This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google books

https://books.google.com

UNIVERSITY OF CALIFORNIA, SANTA CRUZ
3 2106 02066 6332

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

RECORDS

OF THE

SURVEY OF INDIA

Volume X

ANNUAL REPORTS OF

PARTIES AND OFFICES

1915-16.

PREPARED UNDER THE DIRECTION OF

Colonel Sir S. G. BURRARD, K. C. S. I., R. E., F. R. S.

Surveyor General of India.

DEHRA DŪN
PRINTED AT THE OFFICE OF THE TRIGONOMETRICAL SURVEY
1917

Price Four Rupees or Five Shillings and Four Pence.

Digitized by Google

Digitized by Google

LICK OBS
QB
296
I39
V. 10

Survey of India.

Roll of Honour.

Captain E. C. Baker, R. E.

Captain G. F. T. Oakes, R. E.

Captain J. A. Field, R. E.

Captain P. G. Huddleston, R. E.

Lieutenant R. L. Almond, R. E.

Lieutenant H. M. McKay, R. E.

Lieutenant V. D. B. Collins.

Digitized by Google

Digitized by Google

Roll of Honour.

SURVEY OF INDIA.

LIEUTENANT R. L. ALMOND, R.E.

Born 13th January 1887.

Entered the Army, 18th December 1907.

Appointed to the Survey of India, 21st December 1912.

KILLED IN ACTION AT NEUVE CHAPELLE, FRANCE ON OR ABOUT 28TH OCTOBER 1914 WHILE SERVING WITH 3RD SAPPERS AND MINERS.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1917

Digitized by Google

Digitized by Google

Roll of Honour.

SURVEY OF INDIA

LIEUTENANT H. M. McKAY, R.E.

Born 6th December 1888.

Entered the Army, 29th July 1908.

Appointed to the Survey of India, 11th December 1912.

KILLED IN ACTION IN FRANCE, ON 13TH NOVEMBER 1914.

While serving with 3rd Sappers and Miners.

Photo engraved & printed at the Office of the Survey of India

Digitized by Google

Digitized by Google

Roll of Honour.

SURVEY OF INDIA

[illegible]

[illegible]

[illegible] 17th December 1915

[illegible] MAY 1915 WHILST [illegible] KING EDWARD [illegible] OWN GURKHA RIFLES [illegible]

[illegible]

Digitized by Google

Digitized by Google

Roll of Honour.

SURVEY OF INDIA

CAPTAIN F[illegible]

[illegible]

[illegible]

KILLED IN [illegible]

Photo-engraved [illegible] at the Office of the Survey of India [illegible]

Digitized by Google

Digitized by Google

Roll of Honour.

CAPTAIN J. A. FIELD, R.E.

Born 2nd May 1884.

Entered the Army, 15th July 1903.

Appointed to the Survey of India, 11th January 1908.

KILLED IN ACTION, IN FRANCE, ON JULY 13th, 1916.

Previous War Service:—Aden Expedition, 1912.

Digitized by Google

Digitized by Google

Roll of Honour.

SURVEY OF INDIA.

CAPTAIN G. F. T. OAKES, R.E.

Born 11th February 1883.
Entered the Army, 21st December 1901.
Appointed to the Survey of India, 2nd March 1907.
DIED OF WOUNDS RECEIVED IN ACTION THE SAME DAY, IN FRANCE ON 15TH JULY 1916.
Previous War Service:—Abor Expedition, 1911-12.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1917

Digitized by Google

Digitized by Google

Roll of Honour.

SURVEY OF INDIA.

CAPTAIN E. C. BAKER, R.E.

Born 1st January 1880.
Entered the Army, 25th June 1900.
Appointed to the Survey of India, 12th January 1906.
Severely wounded in France on September 15th, 1916.
DIED OF HIS WOUNDS ON 19TH SEPTEMBER 1916.
Previous War Service:—Mohmand Field Force, 1908.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1917.

Digitized by Google

Digitized by Google

CONTENTS.

PART I.

TOPOGRAPHICAL SURVEY.

		Page
NORTHERN CIRCLE.	Summary	3
	No. 1 Party	3
	No. 2 Party	5
	No. 3 Party	6
	No. 4 Party	8
	No. 20 Party (Cantonment)	10
	The Riverain Detachment	11
	The Simla Survey Detachment	14
SOUTHERN CIRCLE.	Summary	15
	No. 5 Party	15
	No. 6 Party	16
	No. 7 Party	18
	No. 8 Party	22
EASTERN CIRCLE.	Summary	23
	No. 9 Party	23
	No. 10 Party	24
	No. 11 Party	26
	No. 12 Party	28
Table I.—Out-turns of Detail Survey		30
Table II.—Details of Triangulation and Traversing		32
Table III.—Cost-rates of Survey		34

PART II

GEODETIC AND SCIENTIFIC OPERATIONS.

Astronomical Latitudes.	No. 13 Party.	37
Pendulum Operations.	No. 14 Party.	37
Triangulation.	No. 15 Party.	39
Tidal Operations.	No. 16 Party.	41
Levelling.	No. 17 Party.	51
Magnetic Survey.	No. 18 Party.	61
Base Line.	No. 19 Party.	87
The Computing Office.	Computing Section	87
	Printing Section	89
	Workshops	89
	The Seismograph	91
	Solar Photography	92

Digitized by Google

PART III.

SPECIAL REPORT.

PAGE

TRAVERSE OF THE BOUNDARY OF THE IMPERIAL DELHI AREA 93

APPENDIX.

LIST OF SURVEY OF INDIA PUBLICATIONS 97

ILLUSTRATIONS.

ROPE BRIDGE OVER KISHENGUNGA RIVER IN KASHMIR 3

CHATHAM ISLAND, PORT BLAIR 24

INTEGRATOR FOR CALCULATING ATTRACTIONS.
Designed by MR. J. DE GRAAFF HUNTER 90

TRAVERSE CHART OF IMPERIAL DELHI 93

INDEX MAPS AND CHARTS.

No.

ALL SCALES, MODERN SURVEY AND PUBLICATION. Northern Circle 1
Southern Circle 2
Eastern Circle 3

ONE-INCH SERIES, MODERN.—Northern Circle 4
Southern Circle 5
Eastern Circle 6

do. do. PROVISIONAL EDITION—Northern Circle 7
Eastern Circle 8

HALF-INCH SERIES, MODERN 9

QUARTER-INCH SERIES, MODERN 10

1:1,000,000. "INDIA AND ADJACENT COUNTRIES" SERIES 11

do. CARTE INTERNATIONALE 12

1:2,000,000, 'SOUTHERN ASIA' SERIES 13

CHART OF THE GREAT TRIGONOMETRICAL SURVEY 14

TRIANGULATION PAMPHLETS 15

MAGNETIC SURVEY 16

Digitized by Google

Digitized by Google

The Rope Bridge over the Kishenganga River at [illegible] in the Karnah Tal[illegible] Ka[illegible] Pa[illegible]

From a ph[illegible]

Digitized by Google

PART I.—TOPOGRAPHICAL SURVEY.

NORTHERN CIRCLE.

(*Vide* Index Maps 1 and 4).

Summary.—Four field parties worked in this Circle and completed the detail survey of 8168 square miles of country during the field season of the year under report.

This consists of :—

114	square miles	of	4-inch survey.
495	„	„	„ 4-inch supplementary survey.
391	„	„	„ 2-inch survey.
2320	„	„	„ 1-inch survey.
3997	„	„	„ 1-inch revision survey.
800	„	„	„ 1-inch re-survey.
51	„	„	„ ¼-inch revision survey.

The work of the Riverain Detachment is given in detail on pages 9-12.

No. 20 Party carried out the survey of 18958 and 343 acres on the scales of 16 inches and 64 inches = 1 mile respectively in 13 cantonments during the year. This party also ran 381 linear miles of theodolite traversing as a basis for future detail operations.

The Simla Survey Detachment completed the large-scale survey of Simla during the year, and 14 out of the 32 fair sheets in which the map will be published had been sent for publication by 30th September 1916.

Colonel W. J. Bythell, R. E., proceeded on leave on 23rd November 1915 and was succeeded in charge of the Circle by Lieutenant-Colonel C. L. Robertson, C. M. G., R. E., till the end of the year.

No. 1 PARTY.

By B. R. Hughes.

The office of the party, with bulk of the establishment, remained at Mussoorie throughout the year.

PERSONNEL.

Imperial Officer.

Major E.A. Tandy, R. E., in charge up to 9th June 1916.

Provincial Officers.

Mr. B. R. Hughes, attached from 7th to 9th June 1916 and in charge from 10th June 1916.
Mr. G. J. S. Rae.
„ P. A. T. Kenny.
„ R. C. Hanson.

Upper Subordinate Service.

Khan Bahadur Sher Jang.
Rai Sahib Natha Singh.
Mr. Nanak Chand Puri, B. A.
Rai Sahib Jamna Prasad, from 1st May to 9th September 1916.
Mr. Hamid Gul, from 17th April 1916.
„ Jagdeesh Prasad Vastav (Probationer), from 1st April 1916.

Lower Subordinate Service.

38 Surveyors, etc.

The country surveyed in Jammu was mountainous and the valleys well wooded, and that in Shabkadar open, partly cultivated, plain and barren hills.

The health of the detachments in the field was good. During the recess however a computer, Aftab Bhan, died of cholera.

Topography.—A section of the party had been working in the field since the summer of 1915 in the Kishtwār and Udhampur districts of the Jammu Province of Kashmīr.

The work allotted to it having been completed the section returned to Mussoorie about the middle of December 1915.

This section under Mr. R. C. Hanson with 9 surveyors, completed the survey on the scale of 1 inch = 1 mile in the following sheets :—

Sheets Nos. 43 $\frac{N}{12}$ and 43 $\frac{O}{7, 9, 10, 11, 14 \text{ and } 15}$, also in parts of sheets Nos. 52 $\frac{C}{3, 4, 7 \text{ and } 8}$ and 52 $\frac{D}{1}$.

The outturn was 588 square miles, and the cost-rate of topography Rs. 17·4 per square mile.

Digitized by Google

A small area on the scale of 4 miles = 1 inch was revised by this section in parts of the following sheets:—

Nos. 43 $\frac{N}{12 \text{ and } 16}$ and 43 $\frac{O}{13}$.

The outturn on this scale was 51 square miles, and the cost-rate of topography Rs. 13·3 per square mile.

The heavy cost-rate is due to the fact that the country was difficult of access and the weather inclement, there were difficulties too in obtaining transport.

Another section of the party was sent to the field from Mussoorie about the middle of November 1915, to undertake a military survey on the scale of 4 inches = 1 mile on the Mohmand Frontier between Shabkadar and Michni in the Peshāwar district. This was under Mr. P. A. T. Kenny with a staff of 6 surveyors.

Khan Bahadur Sher Jang also assisted in the preliminary arrangements.

This work lay in parts of sheets Nos. 38 $\frac{N}{8, 11 \text{ and } 12}$.

The outturn was 64·2 square miles, and the cost-rate of topography Rs. 135·9 per square mile.

During December 1915, Major E. A. Tandy, R. E., proceeded to Bīkaner and Pālanpur States and advised the authorities there on the question of town surveys.

At the special request of the Bīkaner Durbar, Mr. Nanak Chand Puri was deputed to supervise the work of the State surveyors and to instruct them in the correct methods of surveying. In addition to this Mr. Nanak Chand Puri did some detail survey with a view to bringing the guide map of Bīkaner up to date; certain traversing was also necessary and a traverser was lent to the State for the purpose of executing a frame work of main and sub-circuits in the city of Bīkaner.

The entire cost of the different classes of work was borne by the State.

Triangulation.— No triangulation in advance has been done during the year under report.

A few further points however were fixed by Mr. Kenny in the course of detail survey in Shabkadar from 4 old stations triangulated by Mr. W. Newland in 1906-07, but as the area was small, *viz*: 16 square miles, and the work took only 3 days, no cost-rates have been taken out.

Traversing.—To supplement the triangulation in the flat portion of the Shabkadar area, traverses, of a total of 15 linear miles, were carried out by Mr. P. A. T. Kenny and one traverser. The cost-rate of this works out to Rs. 15·1 per linear mile.

Recess duties.—Nine fair sheets have been drawn and sent in for publication on the scale of 1 inch = 1 mile, *viz*:—sheets Nos. 43 $\frac{K}{11, 12, 15 \text{ and } 16}$, 43 $\frac{L}{9}$, 43 $\frac{N}{12}$, 43 $\frac{O}{3 \text{ and } 4}$ and 52 $\frac{C}{7}$. With the exception of sheet No. 52 $\frac{C}{7}$ all of them are of the previous year's survey.

The fair drawing of sheet No. 43 $\frac{N}{12}$, which had been partly surveyed and fair drawn in previous year, and of which the survey had been completed during the year under report, was also completed, and the sheet submitted for publication.

Ten fair sheets are in hand, and will be sent in for publication shortly, *viz*:—sheets Nos. 43 $\frac{O}{5, 7, 9, 10, 11, 14 \text{ \& } 15}$ and 52 $\frac{C}{3, 4 \text{ \& } 8}$. Of these, sheet No. 43 $\frac{O}{5}$ was surveyed prior to 1915-16. The fair drawing of one sheet, No. 52 $\frac{D}{1}$, has not yet been commenced.

The outturn of mapping on the 1½-inch scale, for publication on that of 1-inch, was 2340 square miles, and the cost-rate Rs. 11·8 per square mile.

The three sheets of the Shabkadar survey have all been sent in for publication on the scale of 4 inches = 1 mile.

The outturn was 64 square miles and the cost-rate Rs. 40·0 per square mile.

Three sheets of the half-inch mapping have been sent in for publication, *viz*:—sheets Nos. 43 $\frac{G}{\text{N.E., S.E. \& S.W.}}$.

Four more sheets are nearing completion, *viz*:—Nos. 38 $\frac{O}{\text{S.E. \& S.W.}}$, 43 $\frac{G}{\text{N.W.}}$ and another.

The cost-rate of this mapping is Rs. 5·0 per square mile.

The computations in connection with the Bīkaner traverse were all completed during the course of that work.

Digitized by Google

This party also helped in the fair drawing, etc., of the Basrah Survey Party at Mussoorie during August and September by lending the services of 7 surveyors, etc., at a cost of Rs. 295. The expenditure has been borne by No. 1 Party and has gone to swell cost-rates of the party.

Inspections.—The party was inspected once by the Surveyor General and on several occasions by the Superintendent, Northern Circle.

The Superintendent, Map Publication also visited the party at Mussoorie in August.

No. 2 PARTY.

By T. W. Babonau.

The head-quarters of the party remained at Mussoorie throughout the year. The party was employed in the field in triangulating and traversing, and in executing one-inch survey in the districts of Hissār, Rohtak and Gurgaon and in the States of Jīnd, Pataudi, Dujāna, Alwar, Bīkaner, Jaipur, Lohāru, Bharatpur, Nābha and Patiāla.

The nature of country covered by the one-inch survey was undulating with numerous sandhills and occasional hills; that over which the triangulation extended was fairly hilly, rising to an average of 2500 feet. Half the area of these hills was covered by State forests. Traverses were run in flat country where triangulation was impracticable.

Personnel.

Provincial Officers.

Mr. B. R. Hughes, in charge to 6th June 1916.
" T. W. Babonau, in charge from 7th June 1916.
" F. B. Powell.
" Kanak Singh, up to 21st March 1916.
" R. E. Saubolle.
" J. H. Johnson
" J. A. Calvert.

Upper Subordinate Service.

Mr. Chuni Lal Kapur.
Ghulam Hasan (Probationer), from 1st April 1916.

Lower Subordinate Service.

30 Surveyors, etc.

The field season began on the 9th November 1915, and ended on the 4th April 1916.

The health of the establishment was good throughout the season.

Topography.—The survey was executed in 11 sheets, *viz*:—

Sheets Nos. 44 $\frac{P}{9, 10, 13, 14 \& 15}$ and 53 $\frac{D}{3, 4, 7, 8, 12 \& 16}$.

One camp, consisting of Mr. Chuni Lal Kapur and twelve surveyors, under Mr. Saubolle, carried out the survey of these sheets.

It was based on the plotted village trijunctions, where old data was forthcoming, and on trigonometrically intersected points elsewhere.

Where a comparison of the co-ordinate values of identical points as derived from triangulation and from revenue survey operations was possible, a discrepancy of over 200 feet was found.

The outturn of the party was:—

			Square miles.
Revision survey on scale of 1 inch = 1 mile	...	...	1043
Original survey on scale of 1 inch = 1 mile	...	...	1602
	Total	...	2645

The average cost-rate of the topography was Rs. 8 per square mile.

Triangulation for ½-inch detail survey was carried out in sheets Nos. 54 $\frac{A}{11, 12, 15 \& 16}$, and in portions of sheets Nos. 54 $\frac{A}{7 \& 8}$. Mr. Calvert was employed on this and completed 1260 square miles.

The cost-rate, including that of computation, works out to Rs. 6·6 per square mile.

Traversing, with theodolite and chain was run in sheets Nos. 54 $\frac{E}{3, 4, 6, 7, 11 \& 12}$. The positions of conspicuous objects were intersected from the traverse stations. 313 linear miles of this traverse were completed.

The cost-rate including computation works out to Rs. 9 per linear mile.

Recess duties.—(*a*) The fair drawing was executed on the one and a half inch scale for reduction to one-inch by one drawing section under Mr. Johnson and one typing section under Mr. Saubolle; the average number of surveyors employed therein was nine. Mr. Ghulam Hasan drew outline sheet No. 44 $\frac{D}{12}$, and helped generally in the work of these sections.

The drawing of most of the 1-inch sheets was carried out partly by the direct process.

All the fair drawing of sheets Nos. 44 $\frac{P}{10, 14 \& 15}$ and 53 $\frac{D}{3, 4, 7, 8 \& 12}$ remained incomplete at the end of the survey year. This was due largely to the demands of the Basrah Survey Party for skilled draftsmen.

Digitized by Google

Cost-rate of this fair drawing works out to Rs. 6·15 per square mile.

(*b*) The fair drawing of the half-inch section was continued throughout the recess season under Mr. F. B. Powell, whose mapping section remained in Mussoorie throughout the whole year under report.

10 half-inch sheets were submitted for publication, and five are under preparation. Seven of the sheets submitted for publication were completed to margin from old surveys on the half-inch, the remaining portions being compiled from modern one-inch published sheets.

The cost-rate of half-inch fair drawing works out to Rs. 2·15 per square mile.

(*c*) The computations of the triangulation and traversing and the plotting of the results were carried out by Messrs. Calvert and Chuni Lal Kapur and a computer and completed by the middle of September.

The cost-rate of the computations works out to Rs. 2·4 per square mile.

Miscellaneous.—(*a*) A four-inch survey of the head works of the Lower Bāri Doāb Canal and the surrounding country was executed for the Irrigation Branch of the Punjab Public Works Department. This was fair drawn on the same scale, and supplied to the Executive Engineer, 1st Division, Lower Bāri Doāb Canal with an index on the 1-inch scale.

As the fair mapping has not been completed, the cost of the work cannot be submitted.

(*b*) Mr. Kanak Singh did not take the field, but was employed on the ½-inch mapping of No. 3 Party to the date of his retirement on 21st March 1916. This work was then taken over by Mr. J. H. Johnson who returned from 2 months' privilege leave on 1st March.

Inspections.—The Superintendent, Northern Circle, inspected the party during recess.

The Surveyor General inspected the party in the month of September 1916.

No. 3 PARTY.

By H. H. B. Hanby.

The programme of the party lay in the United Provinces, and embraced parts of the districts of Meerut, Bijnor, Morādābād, Garhwāl, Almorā, Nainī Tāl and Rāmpur State (Rohilkhand). It surveyed an area of 3088 square miles on all scales. Triangulation and traversing were also carried out in advance for future surveys on scales of 4 inches, and 1 inch to a mile.

The southern half of the area under survey is practically flat except for the presence of a series of low sandy ridges, running generally parallel to the Ganges river. The low lying *khādar* land on both banks of the Ganges is covered with tall grass. Dense forest growth was met with along the foot-hills of southern Garhwāl, and in parts of the Kāshīpur *tahsīl* and Bhābar of district Nainī Tāl. The northern half consists of densely forest-clad and intricate hills, the greater part of which is reserved forest. The only rivers of importance flowing through the work are the Ganges and the Rāmgangā.

PERSONNEL.

Provincial Officers.

Mr. H.H.B. Hanby, in charge.
" E. J. Biggie.
" A. M. Talati.
" H. T. Hughes.
" G. E. R. Cooper.
" Moqimuddin.

Upper Subordinate Service.

Mr. Mahomed Lutf Ali.
" Muhammad Husain.
" A. A. S. Matlub Ahmad (Probationer), from 1st April 1916.

Lower Subordinate Service.

53 Surveyors, etc.

The field head-quarters of the party opened at Najībābād on the 8th November 1915, and returned to Mussoorie on the 1st May 1916. Field operations however continued till the end of June 1916.

The health of the party during the field was, on the whole, fair, but during recess, seven men were given leave for various periods on account of ill health and one unclassified draftsman died of cholera in Mussoorie.

Topography.—The area surveyed embraced the following sheets, *viz*:—the whole of sheets Nos. $53\frac{K}{4,5,8,9,10,12,13,15\ \&\ 16}$ and parts of sheets Nos. $53\frac{K}{14}$ and $53\frac{O}{2,6,7,10\ \&\ 11}$.

The surveyors were divided into 4 camps; Mr. E. J. Biggie was in charge of the survey of sheets Nos. $53\frac{K}{5,9,10,13\ \&\ 14}$; Mr. G. E. R. Cooper of that of the 4-inch forest survey that lay in sheets Nos. $53\frac{O}{2,6,7,10\ \&\ 11}$; Mr. Moqimuddin of that of sheets Nos. $53\frac{K}{4,8,12\ \&\ 16}$; and Mr. Mahomed Lutf Ali of that of sheet No. $53\frac{K}{15}$ and the 28 four-inch sheets of the Rāmnagar Forest Division, *viz*:— Nos. 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 26(a), 27, 28, 29, 30, 31, 31(a), 32, 33, 34, 35, 37, 38, 39, 40, 44 and 45.

Digitized by Google

Blue prints of sheets Nos. 53 $\frac{K}{4, 8, 12 \& 16}$ were obtained from Calcutta on drawing paper mounted on cloth, these were then mounted on to plane-tables, and revised in the field.

The result of the theodolite traverse over 398 linear miles, executed during season 1914-15, was plotted on the existing 4-inch maps of the Rāmnagar Forest Division, and the supplementary information for which the forest officials had asked was surveyed on the sheets concerned.

The 4-inch work in sheets Nos. 53 $\frac{O}{2, 6 \& 7}$ is a special survey of the Kosī Forest Range, and a part of the China Forest Range. The work in sheets Nos. 53 $\frac{O}{10 \& 11}$ falls in part of the Mukteswar reserved forest and was specially asked for by the Imperial Bacteriologist.

To meet the requirements of the Forest Department the reserved forests within sheets Nos. 53 $\frac{K}{5, 9, 13 \& 14}$ were surveyed on the 2-inch scale. At the commencement of operations each surveyor was given two boards, the forest areas being surveyed on the 2-inch scale, and the intervening spaces on the 1-inch, but the constant break of scale proved troublesome, and, as there was no appreciable saving in time, it was decided later, to survey wholly on the 2-inch scale all future boards which contained a fair amount of reserved forest areas within their limits. As the Forest Department have specially asked for the intervening areas, the survey of these, on the 2-inch scale, seems justified.

The outturn of the party is as follows:—

(a) Revision survey	on scale of	1 inch	= 1 mile	2152	square miles.
(b) Original	„ „	2 inches	„	391	„
(c) „	„ „	4 „	„	50	„
(d) Supplementary	„ „	4 „	„	495	„

The cost-rate of (a) is Rs. 16·8 per square mile.
„ „ (b) „ 19·5 „ „
„ „ (c) „ 154·2 „ „
„ „ (d) „ 8·4 „ „

Triangulation.—The area triangulated embraces parts of the following sheets, *viz*:— sheets Nos. 53 $\frac{K}{5 \& 13}$ and 53 $\frac{O}{6, 7, 10, 11, 12 \& 15}$. Mr. E. J. Biggie worked in sheets Nos. 53 $\frac{K}{5 \& 13}$, and Mr. A. M. Talati in sheets Nos. 53 $\frac{O}{6, 7, 10, 11, 12 \& 15}$. The total area triangulated amounts to 745 square miles; of this, 260 square miles are for future special forest surveys on the 4-inch scale, and 485 square miles for 1-inch work. Of the latter area, 149 square miles triangulated by Mr. Biggie, came under survey during the season under report, the computations being done in the field.

The cost-rate of the triangulation for 1-inch survey is Rs. 6·4 per square mile.
„ „ „ 4-inch „ „ 28·3 „

Traversing.—The area traversed embraces parts of the following sheets, *viz*:— sheets Nos. 53 $\frac{O}{4, 7, 8, 10, 11 \& 12}$. The control of the traverse camp remained under the officer in charge of the party.

The total number of linear miles traversed is 966. Of this 512 linear miles are for special 4-inch forest survey, and 454 linear miles for 1-inch topographical survey.

The cost-rate of the traversing for 1-inch survey is Rs. 16·7 per linear mile.
„ „ „ „ 4-inch „ „ 27·1 „ „

Recess Duties.—(*a*) During the recess the party undertook the fair drawing of 14 sheets on various scales. Mr. E. J. Biggie supervised the drawing of the following 8 sheets, *viz*:— sheet No. 53 $\frac{K}{N.E.}$, for publication on the ½-inch scale, and sheets Nos. 53 $\frac{K}{5}$ N & S, 53 $\frac{K}{9}$ N & S, 53 $\frac{K}{13}$ N & S, and 53 $\frac{K}{14}$ N, for publication on the 2-inch scale. Mr. Moqimuddin commenced the fair drawing of the following 4 sheets, *viz*:—sheets Nos. 53 $\frac{K}{4, 8, 12 \& 16}$. On his proceeding on privilege leave from 31st July, Mr. G. E. R. Cooper took charge of the drawing of these sheets in addition to that of sheets Nos. 53 $\frac{K}{15}$ and 53 $\frac{K}{N.W.}$. Sheets Nos. 53 $\frac{K}{4, 8, 12, 15 \& 16}$ are for publication on the 1-inch scale, and 53 $\frac{K}{N.W.}$ on the ½-inch. None of these sheets were submitted for publication during the season under report. The following sheets have been completed and will be submitted for publication during October and November:—sheets Nos. 53 $\frac{K}{4, 8, 12, 15 \& 16}$.

A section is being left at Mussoorie to carry on the fair drawing of the undermentioned sheets during the winter, *viz*:—sheets Nos. 53 $\frac{K}{5}$ N & S, 53 $\frac{K}{9}$ N & S, 53 $\frac{K}{13}$ N & S, 53 $\frac{K}{14}$ N, 53 $\frac{K}{N.W.}$ and 53 $\frac{K}{N.E.}$. Sheets Nos. 53 $\frac{K}{5 \& 10}$ will probably be drawn on the 1½-inch scale for publication on the scale 1 inch = 1 mile during the winter.

Digitized by Google

Owing to the lateness of the completion of field work, the 2-inch mapping was not commenced till the end of July, and this accounts for the backward state of the sheets.

The cost-rate of ¾-inch mapping for ½-inch publication is Rs. 2·3 per square mile.
" " 1½-inch " " 1-inch " " 8·3 "
" " 2-inch " " 2-inch " " 9·1 "

(*b*) The computations of the following areas were completed:—

(1) 260 square miles of triangulation for 4-inch survey
(2) 336 " " " " " 1-inch " (stations only)
(3) 512 linear " of traversing for 4-inch survey
(4) 454 " " " " " 1-inch "

No triangulation charts have been drawn.

Miscellaneous.—(*a*) Surveyors, with previous experience of forest work, were selected to undertake the 4-inch survey of the Nainī Tāl forests, and it was expected that they would be able to turn out at least 4 square miles per month, but this hope was not realised, owing to the intricate nature of the ground over which the work was carried out. The Government Notification supplied by the Forest Department, giving a description of the boundaries was found to be very incorrect, and at the request of the Conservator of Forests (Kumaun Circle) who personally visited the area under survey, Mr. G. E. R. Cooper carried out the necessary corrections, while supervising the survey work.

When the survey of the forest areas is asked for by the Forest Department, enquiries should be made, whether all lines have been cleared, and masonry boundary pillars erected. No survey work should be undertaken unless answers to these questions are in the affirmative. The preliminary work in connection with the forest surveys in district Nainī Tāl was started by this party, under the belief that these two very important points had received due attention on the part of the Forest Department, but this did not prove to be the case; and the result has been that the traversers have had to do their own line clearing in places before they could proceed with their observations. There were instances too, where masonry pillars had not been built. These set-backs materially affected the progress of the work. In addition to the clearing of lines along the external limits of reserved forests, the clearing of lines of all notified exclusions should also be insisted upon.

(*b*) One soldier surveyor, one pupil surveyor, four pupil draftsmen and one pupil traverser received instructions in the field.

Inspections.—The party was inspected during recess by the Superintendent, Northern Circle, and also by the Surveyor General.

No. 4 PARTY.

By H. W. Biggie.

The work of the party included resurvey and revision survey in the United Provinces, and a small isolated area of survey in Nepāl. The portion in the United Provinces lay in fairly open plains; while the isolated area lay in the Nepāl *tarai*.

The two detachments of the party assembled at Fyzābād on 11th October 1915 for field work, which was closed on 1st May 1916 the head-quarters of the party remained at Mussoorie throughout the year.

The health of the party was good, only one member having to go on combined leave for six months owing to ill health.

Personnel.

Provincial Officers.

Mr. H. W. Biggie, in charge.
" H. P. D. Morton.
" J. C. C. Lears.
" Duni Chand Puri.

Upper Subordinate Service.

Mr. Mohammad Husain Khan.
" Daulat Ram Vohra (Probationer) from 1st April 1916.

Lower Subordinate Service.

28 Surveyors, etc.

Topography.—The portion of country dealt with by the party in the United Provinces consists of flat plains which are well cultivated. Orchards, containing mango trees, are numerous but there are no forests, though scrub growth occurs in some places. Village sites are numerous, and the density of the population is very high. The only river of importance which flows through the work is the Gogrā. The small area in Nepāl State lies in the Nepāl *tarai*, along the border of the Bahraich district. This area consists of about two-fifths of fairly open plains, the remainder being low hills very densely clad on their lower slopes with forest and under growth, the chief timber being *sāl* (Shorea robusta). The upper slopes and summits

Digitized by Google

of the hills are covered in spear-grass. They are locally known as the *Dundwa* Range and are separated here from the main Himālayas by the valley of the Rāptī river, which, for a short distance, lies in the western area of the work.

Mr. Morton, with two surveyors to help him, took a personal share in, and was in charge of, the work in Nepāl State in which sheet No. 63 $\frac{E}{13}$ was completed to margin. Mr. Muhammad Husain Khan's camp dealt with sheets Nos. 63 $\frac{J}{12 \& 15}$ and 63 $\frac{N}{3, 4, 7 \& 8}$, in the United Provinces. He had seven surveyors, strengthened in the middle of the field season by one more from Mussoorie. Towards the end of March Mr. Morton's camp completed its work, and he then took over the camp under Mr. Muhammad Husain Khan, who proceeded on privilege leave.

The following sheets were completed on the 1-inch scale:—survey, the Nepāl portion of sheet No. 63 $\frac{E}{13}$; re-survey, sheets Nos. 63 $\frac{J}{15}$ and 63 $\frac{N}{3 \& 7}$; revision survey, sheets Nos. 63 $\frac{J}{12}$ and 63 $\frac{N}{4 \& 8}$. The areas completed under survey, re-survey and revision survey are 130, 800 and 802 square miles respectively, making a total of 1732 square miles, the cost-rate of detail survey working out at Rs. 10·0 per square mile.

Triangulation.—The triangulation of the Nepāl portion of sheet No. 63 $\frac{E}{13}$, amounting to 107 square miles, was carried out by Mr. E. J. Biggie. This area was subsequently surveyed in detail and is dealt with above. It lies at a distance of about 25 miles from the North-East Longitudinal Series of triangulation with which the new work was connected. A belt of dense *sāl* forest lies between the old and the new work, and was the main difficulty in linking up.

The cost-rate is Rs. 65·3 per square mile. This high rate is due to the fact that, though area was taken credit for during the previous survey year, no cost was debited against it, nor cost-rate taken out.

Traversing.—No traversing was done by the party.

Recess duties.—(*a*) The supervision of the fair drawing, which continued at Mussoorie throughout the year, was divided up as follows:—Mr. Morton, current fair drawing of 1-inch sheets Nos. 63 $\frac{N}{3, 4, 7 \& 8}$ and the Nepāl portion of sheet No. 63 $\frac{E}{13}$; Mr. Lears, current fair drawing of 1-inch sheets Nos. 63 $\frac{J}{12 \& 15}$, ½-inch sheets Nos. 34 $\frac{J}{N. W.}$ and 34 $\frac{J}{N. E.}$ and of 1-inch sheets Nos. 63 $\frac{F}{16}$ and 63 $\frac{J}{8, 10, 11 \& 16}$, which had been left over from 1914-15; Mr. Duni Chand Puri, ½-inch sheets Nos. 34 $\frac{J}{S. W.}$, 34 $\frac{J}{S. E.}$, 34 $\frac{K}{N. E.}$ and 38 $\frac{O}{N. E.}$ and 1-inch sheets 63 $\frac{F}{14 \& 15}$ and 63 $\frac{J}{2, 3, 6 \& 7}$, left over from 1914-15.

The number of names in the 1-inch sheets of the parts of the United Provinces which came under survey during the year is very great, and the typing of these sheets is therefore a tedious matter.

The following twelve 1-inch sheets left over from 1914-15 with a total area of 3201 square miles were submitted for publication to the head-quarters office during the year:—sheets Nos. 63 $\frac{F}{14, 15 \& 16}$ and 63 $\frac{J}{2, 3, 4, 6, 7, 8, 10, 11 \& 16}$.

The fair drawing of the Nepāl portion of 1-inch sheet, No. 63 $\frac{E}{13}$, and ½-inch sheets Nos. 34 $\frac{J}{N. W., N. E., S. W. \& S. E.}$, is practically complete.

The cost-rate for 1-inch mapping is Rs. 22·1 per square mile, for ½-inch mapping Rs. 2·4 per square mile and for compilation of village boundary editions Re. 0·8 per square mile; the average cost-rate for all being Rs. 3·6 per square mile.

(*b*) Other recess duties comprised the working out of all the rectangular co-ordinates of trijunctions and points for field work in sheets Nos. 63 $\frac{M}{4}$ and 63 $\frac{N}{1, 2, 5 \& 6}$, during season 1916-17, and the compilation and preparation by a small staff, of special editions of 1-inch sheets showing village boundaries. The following fourteen sheets of the village boundary edition were submitted during the year:—sheets Nos. 54 $\frac{M}{15}$, 54 $\frac{N}{14}$, 62 $\frac{H}{12}$, 63 $\frac{A}{1 \& 2}$, 63 $\frac{B}{2 \& 7}$ and 63 $\frac{E}{9, 10, 11, 12, 14, 15 \& 16}$. Eight more sheets are practically complete.

Miscellaneous.—As an attempt to obviate the necessity for traversing for the purpose of providing additional points for detail survey, the fullest possible use was made of the old traverse records of the department; and the co-ordinates of all trijunctions and points occurring in those records were extracted. The success of the experiment was proved by the data thus obtained being found ample for the carrying out of detail survey, and no additional traversing was necessary during the field season. The same exhaustive means of providing a sufficiency of points have been adopted again this year for detail survey during the ensuing

Digitized by Google

PART III.

SPECIAL REPORT.

PAGE

TRAVERSE OF THE BOUNDARY OF THE IMPERIAL DELHI AREA 93

APPENDIX.

LIST OF SURVEY OF INDIA PUBLICATIONS 97

ILLUSTRATIONS.

ROPE BRIDGE OVER KISHENGUNGA RIVER IN KASHMIR 3

CHATHAM ISLAND, PORT BLAIR 24

INTEGRATOR FOR CALCULATING ATTRACTIONS.
Designed by MR. J. DE GRAAFF HUNTER 90

TRAVERSE CHART OF IMPERIAL DELHI 93

INDEX MAPS AND CHARTS.

No.

ALL SCALES, MODERN SURVEY AND PUBLICATION. Northern Circle 1
Southern Circle 2
Eastern Circle 3

ONE-INCH SERIES, MODERN.—Northern Circle 4
Southern Circle 5
Eastern Circle 6

do. do. PROVISIONAL EDITION—Northern Circle 7
Eastern Circle 8

HALF-INCH SERIES, MODERN 9

QUARTER-INCH SERIES, MODERN 10

1: 1,000,000. "INDIA AND ADJACENT COUNTRIES" SERIES 11

do. CARTE INTERNATIONALE 12

1: 2,000,000, 'SOUTHERN ASIA' SERIES 13

CHART OF THE GREAT TRIGONOMETRICAL SURVEY 14

TRIANGULATION PAMPHLETS 15

MAGNETIC SURVEY 16

Digitized by Google

Digitized by Google

PART III.

SPECIAL REPORT.

PAGE

TRAVERSE OF THE BOUNDARY OF THE IMPERIAL DELHI AREA 93

APPENDIX.

LIST OF SURVEY OF INDIA PUBLICATIONS 97

ILLUSTRATIONS.

ROPE BRIDGE OVER KISHENGUNGA RIVER IN KASHMIR 3
CHATHAM ISLAND, PORT BLAIR 24
INTEGRATOR FOR CALCULATING ATTRACTIONS.
Designed by MR. J. DE GRAAFF HUNTER 90
TRAVERSE CHART OF IMPERIAL DELHI 93

INDEX MAPS AND CHARTS.

No.

ALL SCALES, MODERN SURVEY AND PUBLICATION. Northern Circle 1
Southern Circle 2
Eastern Circle 3

ONE-INCH SERIES, MODERN.—Northern Circle 4
Southern Circle 5
Eastern Circle 6

do. do. PROVISIONAL EDITION—Northern Circle 7
Eastern Circle 8

HALF-INCH SERIES, MODERN 9
QUARTER-INCH SERIES, MODERN 10

1: 1,000,000. "INDIA AND ADJACENT COUNTRIES" SERIES 11
do. CARTE INTERNATIONALE 12
1: 2,000,000, 'SOUTHERN ASIA' SERIES 13

CHART OF THE GREAT TRIGONOMETRICAL SURVEY 14
TRIANGULATION PAMPHLETS 15
MAGNETIC SURVEY 16

Digitized by Google

Digitized by Google

PART III.

SPECIAL REPORT.

PAGE

TRAVERSE OF THE BOUNDARY OF THE IMPERIAL DELHI AREA 93

APPENDIX.

LIST OF SURVEY OF INDIA PUBLICATIONS 97

ILLUSTRATIONS.

ROPE BRIDGE OVER KISHENGUNGA RIVER IN KASHMIR 3
CHATHAM ISLAND, PORT BLAIR 24
INTEGRATOR FOR CALCULATING ATTRACTIONS.
Designed by MR. J. DE GRAAFF HUNTER 90
TRAVERSE CHART OF IMPERIAL DELHI 93

INDEX MAPS AND CHARTS.

No.

ALL SCALES, MODERN SURVEY AND PUBLICATION. Northern Circle 1
Southern Circle 2
Eastern Circle 3

ONE-INCH SERIES, MODERN.—Northern Circle 4
Southern Circle 5
Eastern Circle 6

do. do. PROVISIONAL EDITION—Northern Circle 7
Eastern Circle 8

HALF-INCH SERIES, MODERN 9
QUARTER-INCH SERIES, MODERN 10

1:1,000,000. "INDIA AND ADJACENT COUNTRIES" SERIES 11
do. CARTE INTERNATIONALE 12
1:2,000,000, 'SOUTHERN ASIA' SERIES 13

CHART OF THE GREAT TRIGONOMETRICAL SURVEY 14
TRIANGULATION PAMPHLETS 15
MAGNETIC SURVEY 16

Digitized by Google

Digitized by Google

PART III.

SPECIAL REPORT.

PAGE

TRAVERSE OF THE BOUNDARY OF THE IMPERIAL DELHI AREA 93

APPENDIX.

LIST OF SURVEY OF INDIA PUBLICATIONS 97

ILLUSTRATIONS.

ROPE BRIDGE OVER KISHENGUNGA RIVER IN KASHMIR 3

CHATHAM ISLAND, PORT BLAIR 24

INTEGRATOR FOR CALCULATING ATTRACTIONS.
Designed by MR. J. DE GRAAFF HUNTER 90

TRAVERSE CHART OF IMPERIAL DELHI 93

INDEX MAPS AND CHARTS.

No.

ALL SCALES, MODERN SURVEY AND PUBLICATION. Northern Circle 1
Southern Circle 2
Eastern Circle 3

ONE-INCH SERIES, MODERN.—Northern Circle 4
Southern Circle 5
Eastern Circle 6

do. do. PROVISIONAL EDITION—Northern Circle 7
Eastern Circle 8

HALF-INCH SERIES, MODERN 9

QUARTER-INCH SERIES, MODERN 10

1: 1,000,000. "INDIA AND ADJACENT COUNTRIES" SERIES 11

do. CARTE INTERNATIONALE 12

1: 2,000,000, 'SOUTHERN ASIA' SERIES 13

CHART OF THE GREAT TRIGONOMETRICAL SURVEY 14

TRIANGULATION PAMPHLETS 15

MAGNETIC SURVEY 16

Digitized by Google

Digitized by Google

Digitized by Google

Roll of Honour.

SURVEY OF INDIA.

CAPTAIN E. C. BAKER, R.E.

Born 1st January 1880.
Entered the Army, 25th June 1900.
Appointed to the Survey of India, 12th January 1906.
Severely wounded in France on September 15th, 1916.
DIED OF HIS WOUNDS ON 19TH SEPTEMBER 1916.
Previous War Service:—Mohmand Field Force, 1908.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1917

Digitized by Google

Digitized by Google

CONTENTS.

PART I.

TOPOGRAPHICAL SURVEY.

		Page
NORTHERN CIRCLE.	Summary	3
	No. 1 Party	3
	No. 2 Party	5
	No. 3 Party	6
	No. 4 Party	8
	No. 20 Party (Cantonment)	10
	The Riverain Detachment	11
	The Simla Survey Detachment	14
SOUTHERN CIRCLE.	Summary	15
	No. 5 Party	15
	No. 6 Party	16
	No. 7 Party	18
	No. 8 Party	22
EASTERN CIRCLE.	Summary	23
	No. 9 Party	23
	No. 10 Party	24
	No. 11 Party	26
	No. 12 Party	28
Table I.—Out-turns of Detail Survey		30
Table II.—Details of Triangulation and Traversing		32
Table III.—Cost-rates of Survey		34

PART II

GEODETIC AND SCIENTIFIC OPERATIONS.

Astronomical Latitudes.	No. 13 Party.	37
Pendulum Operations.	No. 14 Party.	37
Triangulation.	No. 15 Party.	39
Tidal Operations.	No. 16 Party.	41
Levelling.	No. 17 Party.	51
Magnetic Survey.	No. 18 Party.	61
Base Line.	No. 19 Party.	87
The Computing Office.	Computing Section	87
	Printing Section	89
	Workshops	89
	The Seismograph	91
	Solar Photography	92

Digitized by Google

PART III.

SPECIAL REPORT.

PAGE

TRAVERSE OF THE BOUNDARY OF THE IMPERIAL DELHI AREA 93

APPENDIX.

LIST OF SURVEY OF INDIA PUBLICATIONS 97

ILLUSTRATIONS.

ROPE BRIDGE OVER KISHENGUNGA RIVER IN KASHMIR 3

CHATHAM ISLAND, PORT BLAIR 24

INTEGRATOR FOR CALCULATING ATTRACTIONS.
Designed by MR. J. DE GRAAFF HUNTER 90

TRAVERSE CHART OF IMPERIAL DELHI 93

INDEX MAPS AND CHARTS.

No.

ALL SCALES, MODERN SURVEY AND PUBLICATION. Northern Circle 1
Southern Circle 2
Eastern Circle 3

ONE-INCH SERIES, MODERN.—Northern Circle 4
Southern Circle 5
Eastern Circle 6

do. do. PROVISIONAL EDITION—Northern Circle 7
Eastern Circle 8

HALF-INCH SERIES, MODERN 9

QUARTER-INCH SERIES, MODERN 10

1:1,000,000. "INDIA AND ADJACENT COUNTRIES" SERIES 11

do. CARTE INTERNATIONALE 12

1:2,000,000, 'SOUTHERN ASIA' SERIES 13

CHART OF THE GREAT TRIGONOMETRICAL SURVEY 14

TRIANGULATION PAMPHLETS 15

MAGNETIC SURVEY 16

Digitized by Google

Digitized by Google

The Rope Bridge over the Kishen[illegible] River at [illegible] near in the Karnah Tahsil Kashmir Provin[illegible]

From a [illegible]

Digitized by Google

PART I.—TOPOGRAPHICAL SURVEY.

NORTHERN CIRCLE.

(*Vide* Index Maps 1 and 4).

Summary.—Four field parties worked in this Circle and completed the detail survey of 8168 square miles of country during the field season of the year under report.

This consists of :—

114	square miles	of	4-inch survey.
495	„	„	„ 4-inch supplementary survey.
391	„	„	„ 2-inch survey.
2320	„	„	„ 1-inch survey.
3997	„	„	„ 1-inch revision survey.
800	„	„	„ 1-inch re-survey.
51	„	„	„ ¼-inch revision survey.

The work of the Riverain Detachment is given in detail on pages 9-12.

No. 20 Party carried out the survey of 18958 and 343 acres on the scales of 16 inches and 64 inches = 1 mile respectively in 13 cantonments during the year. This party also ran 381 linear miles of theodolite traversing as a basis for future detail operations.

The Simla Survey Detachment completed the large-scale survey of Simla during the year, and 14 out of the 32 fair sheets in which the map will be published had been sent for publication by 30th September 1916.

Colonel W. J. Bythell, R. E., proceeded on leave on 23rd November 1915 and was succeeded in charge of the Circle by Lieutenant-Colonel C. L. Robertson, C. M. G., R. E., till the end of the year.

No. 1 PARTY.

By B. R. Hughes.

The office of the party, with bulk of the establishment, remained at Mussoorie throughout the year.

PERSONNEL.

Imperial Officer.

Major E.A. Tandy, R. E., in charge up to 9th June 1916.

Provincial Officers.

Mr. B. R. Hughes, attached from 7th to 9th June 1916 and in charge from 10th June 1916.
Mr. G. J. S. Rae.
„ P. A. T. Kenny.
„ R. C. Hanson.

Upper Subordinate Service.

Khan Bahadur Sher Jang.
Rai Sahib Natha Singh.
Mr. Nanak Chand Puri, B. A.
Rai Sahib Jamna Prasad, from 1st May to 9th September 1916.
Mr. Hamid Gul, from 17th April 1916.
„ Jagdeesh Prasad Vastav (Probationer), from 1st April 1916.

Lower Subordinate Service.

38 Surveyors, etc.

The country surveyed in Jammu was mountainous and the valleys well wooded, and that in Shabkadar open, partly cultivated, plain and barren hills.

The health of the detachments in the field was good. During the recess however a computer, Aftab Bhan, died of cholera.

Topography.—A section of the party had been working in the field since the summer of 1915 in the Kishtwār and Udhampur districts of the Jammu Province of Kashmīr.

The work allotted to it having been completed the section returned to Mussoorie about the middle of December 1915.

This section under Mr. R. C. Hanson with 9 surveyors, completed the survey on the scale of 1 inch = 1 mile in the following sheets :—

Sheets Nos. 43 $\frac{N}{12}$ and 43 $\frac{O}{7, 9, 10, 11, 14 \text{ and } 15}$, also in parts of sheets Nos. 52 $\frac{C}{3, 4, 7 \text{ and } 8}$ and 52 $\frac{D}{1}$.

The outturn was 588 square miles, and the cost-rate of topography Rs. 17·4 per square mile.

Digitized by Google

A small area on the scale of 4 miles = 1 inch was revised by this section in parts of the following sheets:—

Nos. 43 $\frac{N}{12 \text{ and } 16}$ and 43 $\frac{O}{13}$.

The outturn on this scale was 51 square miles, and the cost-rate of topography Rs. 13·3 per square mile.

The heavy cost-rate is due to the fact that the country was difficult of access and the weather inclement, there were difficulties too in obtaining transport.

Another section of the party was sent to the field from Mussoorie about the middle of November 1915, to undertake a military survey on the scale of 4 inches = 1 mile on the Mohmand Frontier between Shabkadar and Michni in the Peshāwar district. This was under Mr. P. A. T. Kenny with a staff of 6 surveyors.

Khan Bahadur Sher Jang also assisted in the preliminary arrangements.

This work lay in parts of sheets Nos. 38 $\frac{N}{8, 11 \text{ and } 12}$.

The outturn was 64·2 square miles, and the cost-rate of topography Rs. 135·9 per square mile.

During December 1915, Major E. A. Tandy, R. E., proceeded to Bīkaner and Pālanpur States and advised the authorities there on the question of town surveys.

At the special request of the Bīkaner Durbar, Mr. Nanak Chand Puri was deputed to supervise the work of the State surveyors and to instruct them in the correct methods of surveying. In addition to this Mr. Nanak Chand Puri did some detail survey with a view to bringing the guide map of Bīkaner up to date; certain traversing was also necessary and a traverser was lent to the State for the purpose of executing a frame work of main and sub-circuits in the city of Bīkaner.

The entire cost of the different classes of work was borne by the State.

Triangulation.— No triangulation in advance has been done during the year under report.

A few further points however were fixed by Mr. Kenny in the course of detail survey in Shabkadar from 4 old stations triangulated by Mr. W. Newland in 1906-07, but as the area was small, *viz*: 16 square miles, and the work took only 3 days, no cost-rates have been taken out.

Traversing.—To supplement the triangulation in the flat portion of the Shabkadar area, traverses, of a total of 15 linear miles, were carried out by Mr. P. A. T. Kenny and one traverser. The cost-rate of this works out to Rs. 15·1 per linear mile.

Recess duties.—Nine fair sheets have been drawn and sent in for publication on the scale of 1 inch = 1 mile, *viz*:—sheets Nos. 43 $\frac{K}{11, 12, 15 \text{ and } 16}$, 43 $\frac{L}{9}$, 43 $\frac{N}{12}$, 43 $\frac{O}{3 \text{ and } 4}$ and 52 $\frac{C}{7}$. With the exception of sheet No. 52 $\frac{C}{7}$ all of them are of the previous year's survey.

The fair drawing of sheet No. 43 $\frac{N}{12}$, which had been partly surveyed and fair drawn in previous year, and of which the survey had been completed during the year under report, was also completed, and the sheet submitted for publication.

Ten fair sheets are in hand, and will be sent in for publication shortly, *viz*:—sheets Nos. 43 $\frac{O}{5, 7, 9, 10, 11, 14 \text{ \& } 15}$ and 52 $\frac{C}{3, 4 \text{ \& } 8}$. Of these, sheet No. 43 $\frac{O}{5}$ was surveyed prior to 1915-16. The fair drawing of one sheet, No. 52 $\frac{D}{1}$, has not yet been commenced.

The outturn of mapping on the 1½-inch scale, for publication on that of 1-inch, was 2340 square miles, and the cost-rate Rs. 11·8 per square mile.

The three sheets of the Shabkadar survey have all been sent in for publication on the scale of 4 inches = 1 mile.

The outturn was 64 square miles and the cost-rate Rs. 40·0 per square mile.

Three sheets of the half-inch mapping have been sent in for publication, *viz*:—sheets Nos. 43 $\frac{G}{\text{N.E., S.E. \& S.W.}}$.

Four more sheets are nearing completion, *viz*:—Nos. 38 $\frac{O}{\text{S.E. \& S.W.}}$, 43 $\frac{G}{\text{N.W.}}$ and another.

The cost-rate of this mapping is Rs. 5·0 per square mile.

The computations in connection with the Bīkaner traverse were all completed during the course of that work.

Digitized by Google

This party also helped in the fair drawing, etc., of the Basrah Survey Party at Mussoorie during August and September by lending the services of 7 surveyors, etc., at a cost of Rs. 295. The expenditure has been borne by No. 1 Party and has gone to swell cost-rates of the party.

Inspections.—The party was inspected once by the Surveyor General and on several occasions by the Superintendent, Northern Circle.

The Superintendent, Map Publication also visited the party at Mussoorie in August.

No. 2 PARTY.

By T. W. Babonau.

The head-quarters of the party remained at Mussoorie throughout the year. The party was employed in the field in triangulating and traversing, and in executing one-inch survey in the districts of Hissār, Rohtak and Gurgaon and in the States of Jīnd, Pataudi, Dujāna, Alwar, Bīkaner, Jaipur, Lohāru, Bharatpur, Nābha and Patiāla.

The nature of country covered by the one-inch survey was undulating with numerous sandhills and occasional hills; that over which the triangulation extended was fairly hilly, rising to an average of 2500 feet. Half the area of these hills was covered by State forests. Traverses were run in flat country where triangulation was impracticable.

Personnel.

Provincial Officers.

Mr. B. R. Hughes, in charge to 6th June 1916.
" T. W. Babonau, in charge from 7th June 1916.
" F. B. Powell.
" Kanak Singh, up to 21st March 1916.
" R. E. Saubolle.
" J. H. Johnson
" J. A. Calvert.

Upper Subordinate Service.

Mr. Chuni Lal Kapur.
Ghulam Hasan (Probationer), from 1st April 1916.

Lower Subordinate Service.

30 Surveyors, etc.

The field season began on the 9th November 1915, and ended on the 4th April 1916.

The health of the establishment was good throughout the season.

Topography.—The survey was executed in 11 sheets, *viz* :—

Sheets Nos. 44 $\frac{P}{9, 10, 13, 14 \& 15}$ and 53 $\frac{D}{3, 4, 7, 8, 12 \& 16}$.

One camp, consisting of Mr. Chuni Lal Kapur and twelve surveyors, under Mr. Saubolle, carried out the survey of these sheets.

It was based on the plotted village trijunctions, where old data was forthcoming, and on trigonometrically intersected points elsewhere.

Where a comparison of the co-ordinate values of identical points as derived from triangulation and from revenue survey operations was possible, a discrepancy of over 200 feet was found.

The outturn of the party was:—

			Square miles.
Revision survey on scale of 1 inch = 1 mile	...	...	1043
Original survey on scale of 1 inch = 1 mile	...	...	1602
	Total	...	2645

The average cost-rate of the topography was Rs. 8 per square mile.

Triangulation for ½-inch detail survey was carried out in sheets Nos. 54 $\frac{A}{11, 12, 15 \& 16}$, and in portions of sheets Nos. 54 $\frac{A}{7 \& 8}$. Mr. Calvert was employed on this and completed 1260 square miles.

The cost-rate, including that of computation, works out to Rs. 6·6 per square mile.

Traversing, with theodolite and chain was run in sheets Nos. 54 $\frac{E}{3, 4, 6, 7, 11 \& 12}$. The positions of conspicuous objects were intersected from the traverse stations. 313 linear miles of this traverse were completed.

The cost-rate including computation works out to Rs. 9 per linear mile.

Recess duties.—(*a*) The fair drawing was executed on the one and a half inch scale for reduction to one-inch by one drawing section under Mr. Johnson and one typing section under Mr. Saubolle; the average number of surveyors employed therein was nine. Mr. Ghulam Hasan drew outline sheet No. 44 $\frac{D}{12}$, and helped generally in the work of these sections.

The drawing of most of the 1-inch sheets was carried out partly by the direct process.

All the fair drawing of sheets Nos. 44 $\frac{P}{10, 14 \& 15}$ and 53 $\frac{D}{3, 4, 7, 8 \& 12}$ remained incomplete at the end of the survey year. This was due largely to the demands of the Basrah Survey Party for skilled draftsmen.

Digitized by Google

Cost-rate of this fair drawing works out to Rs. 6·15 per square mile.

(*b*) The fair drawing of the half-inch section was continued throughout the recess season under Mr. F. B. Powell, whose mapping section remained in Mussoorie throughout the whole year under report.

10 half-inch sheets were submitted for publication, and five are under preparation. Seven of the sheets submitted for publication were completed to margin from old surveys on the half-inch, the remaining portions being compiled from modern one-inch published sheets.

The cost-rate of half-inch fair drawing works out to Rs. 2·15 per square mile.

(*c*) The computations of the triangulation and traversing and the plotting of the results were carried out by Messrs. Calvert and Chuni Lal Kapur and a computer and completed by the middle of September.

The cost-rate of the computations works out to Rs. 2·4 per square mile.

Miscellaneous.—(*a*) A four-inch survey of the head works of the Lower Bāri Doāb Canal and the surrounding country was executed for the Irrigation Branch of the Punjab Public Works Department. This was fair drawn on the same scale, and supplied to the Executive Engineer, 1st Division, Lower Bāri Doāb Canal with an index on the 1-inch scale.

As the fair mapping has not been completed, the cost of the work cannot be submitted.

(*b*) Mr. Kanak Singh did not take the field, but was employed on the ½-inch mapping of No. 3 Party to the date of his retirement on 21st March 1916. This work was then taken over by Mr. J. H. Johnson who returned from 2 months' privilege leave on 1st March.

Inspections.—The Superintendent, Northern Circle, inspected the party during recess.

The Surveyor General inspected the party in the month of September 1916.

No. 3 PARTY.

By H. H. B. Hanby.

The programme of the party lay in the United Provinces, and embraced parts of the districts of Meerut, Bijnor, Morādābād, Garhwāl, Almorā, Nainī Tāl and Rāmpur State (Rohilkhand). It surveyed an area of 3088 square miles on all scales. Triangulation and traversing were also carried out in advance for future surveys on scales of 4 inches, and 1 inch to a mile.

The southern half of the area under survey is practically flat except for the presence of a series of low sandy ridges, running generally parallel to the Ganges river. The low lying *khādar* land on both banks of the Ganges is covered with tall grass. Dense forest growth was met with along the foot-hills of southern Garhwāl, and in parts of the Kāshīpur *tahsīl* and Bhābar of district Nainī Tāl. The northern half consists of densely forest-clad and intricate hills, the greater part of which is reserved forest. The only rivers of importance flowing through the work are the Ganges and the Rāmgangā.

PERSONNEL.

Provincial Officers.

Mr. H.H.B. Hanby, in charge.
" E. J. Biggie.
" A. M. Talati.
" H. T. Hughes.
" G. E. R. Cooper.
" Moqimuddin.

Upper Subordinate Service.

Mr. Mahomed Lutf Ali.
" Muhammad Husain.
" A. A. S. Matlub Ahmad (Probationer), from 1st April 1916.

Lower Subordinate Service.

53 Surveyors, etc.

The field head-quarters of the party opened at Najībābād on the 8th November 1915, and returned to Mussoorie on the 1st May 1916. Field operations however continued till the end of June 1916.

The health of the party during the field was, on the whole, fair, but during recess, seven men were given leave for various periods on account of ill health and one unclassified draftsman died of cholera in Mussoorie.

Topography.—The area surveyed embraced the following sheets, *viz*:—the whole of sheets Nos. $53\frac{K}{4,5,8,9,10,12,13,15\ \&\ 16}$ and parts of sheets Nos. $53\frac{K}{14}$ and $53\frac{O}{2,6,7,10\ \&\ 11}$.

The surveyors were divided into 4 camps; Mr. E. J. Biggie was in charge of the survey of sheets Nos. $53\frac{K}{5,9,10,13\ \&\ 14}$; Mr. G. E. R. Cooper of that of the 4-inch forest survey that lay in sheets Nos. $53\frac{O}{2,6,7,10\ \&\ 11}$; Mr. Moqimuddin of that of sheets Nos. $53\frac{K}{4,8,12\ \&\ 16}$; and Mr. Mahomed Lutf Ali of that of sheet No. $53\frac{K}{15}$ and the 28 four-inch sheets of the Rāmnagar Forest Division, *viz*:— Nos. 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 26(a), 27, 28, 29, 30, 31, 31(a), 32, 33, 34, 35, 37, 38, 39, 40, 44 and 45.

Digitized by Google

Blue prints of sheets Nos. 53 $\frac{K}{4, 8, 12 \& 16}$ were obtained from Calcutta on drawing paper mounted on cloth, these were then mounted on to plane-tables, and revised in the field.

The result of the theodolite traverse over 398 linear miles, executed during season 1914-15, was plotted on the existing 4-inch maps of the Rāmnagar Forest Division, and the supplementary information for which the forest officials had asked was surveyed on the sheets concerned.

The 4-inch work in sheets Nos. 53 $\frac{O}{2, 6 \& 7}$ is a special survey of the Kosī Forest Range, and a part of the China Forest Range. The work in sheets Nos. 53 $\frac{O}{10 \& 11}$ falls in part of the Mukteswar reserved forest and was specially asked for by the Imperial Bacteriologist.

To meet the requirements of the Forest Department the reserved forests within sheets Nos. 53 $\frac{K}{5, 9, 13 \& 14}$ were surveyed on the 2-inch scale. At the commencement of operations each surveyor was given two boards, the forest areas being surveyed on the 2-inch scale, and the intervening spaces on the 1-inch, but the constant break of scale proved troublesome, and, as there was no appreciable saving in time, it was decided later, to survey wholly on the 2-inch scale all future boards which contained a fair amount of reserved forest areas within their limits. As the Forest Department have specially asked for the intervening areas, the survey of these, on the 2-inch scale, seems justified.

The outturn of the party is as follows:—

(a) Revision survey on scale of	1 inch	=	1 mile	2152	square miles.
(b) Original „ „	2 inches		„	391	„
(c) „ „ „	4 „		„	50	„
(d) Supplementary „ „	4 „		„	495	„

The cost-rate of (a) is Rs. 16·8 per square mile.
„ „ (b) „ 19·5 „ „
„ „ (c) „ 154·2 „ „
„ „ (d) „ 8·4 „ „

Triangulation.—The area triangulated embraces parts of the following sheets, *viz*:—sheets Nos. 53 $\frac{K}{5 \& 13}$ and 53 $\frac{O}{6, 7, 10, 11, 12 \& 15}$. Mr. E. J. Biggie worked in sheets Nos. 53 $\frac{K}{5 \& 13}$, and Mr. A. M. Talati in sheets Nos. 53 $\frac{O}{6, 7, 10, 11, 12 \& 15}$. The total area triangulated amounts to 745 square miles; of this, 260 square miles are for future special forest surveys on the 4-inch scale, and 485 square miles for 1-inch work. Of the latter area, 149 square miles triangulated by Mr. Biggie, came under survey during the season under report, the computations being done in the field.

The cost-rate of the triangulation for 1-inch survey is Rs. 6·4 per square mile.
„ „ „ 4-inch „ „ 28·3 „

Traversing.—The area traversed embraces parts of the following sheets, *viz*:— sheets Nos. 53 $\frac{O}{4, 7, 8, 10, 11 \& 12}$. The control of the traverse camp remained under the officer in charge of the party.

The total number of linear miles traversed is 966. Of this 512 linear miles are for special 4-inch forest survey, and 454 linear miles for 1-inch topographical survey.

The cost-rate of the traversing for 1-inch survey is Rs. 16·7 per linear mile.
„ „ „ „ 4-inch „ „ 27·1 „ „

Recess Duties.—(*a*) During the recess the party undertook the fair drawing of 14 sheets on various scales. Mr. E. J. Biggie supervised the drawing of the following 8 sheets, *viz*:— sheet No. 53 $\frac{K}{N.E.}$, for publication on the ½-inch scale, and sheets Nos. 53 $\frac{K}{5}$ N & S, 53 $\frac{K}{9}$ N & S, 53 $\frac{K}{13}$ N & S, and 53 $\frac{K}{14}$ N, for publication on the 2-inch scale. Mr. Moqimuddin commenced the fair drawing of the following 4 sheets, *viz*:—sheets Nos. 53 $\frac{K}{4, 8, 12 \& 16}$. On his proceeding on privilege leave from 31st July, Mr. G. E. R. Cooper took charge of the drawing of these sheets in addition to that of sheets Nos. 53 $\frac{K}{15}$ and 53 $\frac{K}{N.W.}$. Sheets Nos. 53 $\frac{K}{4, 8, 12, 15 \& 16}$ are for publication on the 1-inch scale, and 53 $\frac{K}{N.W.}$ on the ½-inch. None of these sheets were submitted for publication during the season under report. The following sheets have been completed and will be submitted for publication during October and November:—sheets Nos. 53 $\frac{K}{4, 8, 12, 15 \& 16}$.

A section is being left at Mussoorie to carry on the fair drawing of the undermentioned sheets during the winter, *viz*:—sheets Nos. 53 $\frac{K}{5}$ N & S, 53 $\frac{K}{9}$ N & S, 53 $\frac{K}{13}$ N & S, 53 $\frac{K}{14}$ N, 53 $\frac{K}{N.W.}$ and 53 $\frac{K}{N.E.}$. Sheets Nos. 53 $\frac{K}{5 \& 10}$ will probably be drawn on the 1½-inch scale for publication on the scale 1 inch = 1 mile during the winter.

Digitized by Google

Owing to the lateness of the completion of field work, the 2-inch mapping was not commenced till the end of July, and this accounts for the backward state of the sheets.

The cost-rate of ¾-inch mapping for ½-inch publication is Rs. 2·3 per square mile.
" " 1½-inch " " 1-inch " " 8·3 "
" " 2-inch " " 2-inch " " 9·1 "

(*b*) The computations of the following areas were completed:—
(1) 260 square miles of triangulation for 4-inch survey
(2) 336 " " " " " 1-inch " (stations only)
(3) 512 linear " of traversing for 4-inch survey
(4) 454 " " " " " 1-inch "

No triangulation charts have been drawn.

Miscellaneous.—(*a*) Surveyors, with previous experience of forest work, were selected to undertake the 4-inch survey of the Nainī Tāl forests, and it was expected that they would be able to turn out at least 4 square miles per month, but this hope was not realised, owing to the intricate nature of the ground over which the work was carried out. The Government Notification supplied by the Forest Department, giving a description of the boundaries was found to be very incorrect, and at the request of the Conservator of Forests (Kumaun Circle) who personally visited the area under survey, Mr. G. E. R. Cooper carried out the necessary corrections, while supervising the survey work.

When the survey of the forest areas is asked for by the Forest Department, enquiries should be made, whether all lines have been cleared, and masonry boundary pillars erected. No survey work should be undertaken unless answers to these questions are in the affirmative. The preliminary work in connection with the forest surveys in district Nainī Tāl was started by this party, under the belief that these two very important points had received due attention on the part of the Forest Department, but this did not prove to be the case; and the result has been that the traversers have had to do their own line clearing in places before they could proceed with their observations. There were instances too, where masonry pillars had not been built. These set-backs materially affected the progress of the work. In addition to the clearing of lines along the external limits of reserved forests, the clearing of lines of all notified exclusions should also be insisted upon.

(*b*) One soldier surveyor, one pupil surveyor, four pupil draftsmen and one pupil traverser received instructions in the field.

Inspections.—The party was inspected during recess by the Superintendent, Northern Circle, and also by the Surveyor General.

No. 4 PARTY.

By H. W. Biggie.

The work of the party included resurvey and revision survey in the United Provinces, and a small isolated area of survey in Nepāl. The portion in the United Provinces lay in fairly open plains; while the isolated area lay in the Nepāl *tarai*.

The two detachments of the party assembled at Fyzābād on 11th October 1915 for field work, which was closed on 1st May 1916 the head-quarters of the party remained at Mussoorie throughout the year.

The health of the party was good, only one member having to go on combined leave for six months owing to ill health.

PERSONNEL.

Provincial Officers.

Mr. H. W. Biggie, in charge.
" H. P. D. Morton.
" J. C. C. Lears.
" Duni Chand Puri.

Upper Subordinate Service.

Mr. Mohammad Husain Khan.
" Daulat Ram Vohra (Probationer) from 1st April 1916.

Lower Subordinate Service.

28 Surveyors, etc.

Topography.—The portion of country dealt with by the party in the United Provinces consists of flat plains which are well cultivated. Orchards, containing mango trees, are numerous but there are no forests, though scrub growth occurs in some places. Village sites are numerous, and the density of the population is very high. The only river of importance which flows through the work is the Gogrā. The small area in Nepāl State lies in the Nepāl *tarai*, along the border of the Bahraich district. This area consists of about two-fifths of fairly open plains, the remainder being low hills very densely clad on their lower slopes with forest and under growth, the chief timber being *sāl* (Shorea robusta). The upper slopes and summits

Digitized by Google

of the hills are covered in spear-grass. They are locally known as the *Dundwa* Range and are separated here from the main Himālayas by the valley of the Rāptī river, which, for a short distance, lies in the western area of the work.

Mr. Morton, with two surveyors to help him, took a personal share in, and was in charge of, the work in Nepāl State in which sheet No. 63 $\frac{E}{13}$ was completed to margin. Mr. Muhammad Husain Khan's camp dealt with sheets Nos. 63 $\frac{J}{12 \& 15}$ and 63 $\frac{N}{3, 4, 7 \& 8}$, in the United Provinces. He had seven surveyors, strengthened in the middle of the field season by one more from Mussoorie. Towards the end of March Mr. Morton's camp completed its work, and he then took over the camp under Mr. Muhammad Husain Khan, who proceeded on privilege leave.

The following sheets were completed on the 1-inch scale:—survey, the Nepāl portion of sheet No. 63 $\frac{E}{13}$; re-survey, sheets Nos. 63 $\frac{J}{15}$ and 63 $\frac{N}{3 \& 7}$; revision survey, sheets Nos. 63 $\frac{J}{12}$ and 63 $\frac{N}{4 \& 8}$. The areas completed under survey, re-survey and revision survey are 130, 800 and 802 square miles respectively, making a total of 1732 square miles, the cost-rate of detail survey working out at Rs. 10·0 per square mile.

Triangulation.—The triangulation of the Nepāl portion of sheet No. 63 $\frac{E}{13}$, amounting to 107 square miles, was carried out by Mr. E. J. Biggie. This area was subsequently surveyed in detail and is dealt with above. It lies at a distance of about 25 miles from the North-East Longitudinal Series of triangulation with which the new work was connected. A belt of dense *sāl* forest lies between the old and the new work, and was the main difficulty in linking up.

The cost-rate is Rs. 65·3 per square mile. This high rate is due to the fact that, though area was taken credit for during the previous survey year, no cost was debited against it, nor cost-rate taken out.

Traversing.—No traversing was done by the party.

Recess duties.—(*a*) The supervision of the fair drawing, which continued at Mussoorie throughout the year, was divided up as follows:—Mr. Morton, current fair drawing of 1-inch sheets Nos. 63 $\frac{N}{3, 4, 7 \& 8}$ and the Nepāl portion of sheet No. 63 $\frac{E}{13}$; Mr. Lears, current fair drawing of 1-inch sheets Nos. 63 $\frac{J}{12 \& 15}$, ½-inch sheets Nos. 34 $\frac{J}{N. W.}$ and 34 $\frac{J}{N. E.}$ and of 1-inch sheets Nos. 63 $\frac{F}{16}$ and 63 $\frac{J}{8, 10, 11 \& 16}$, which had been left over from 1914-15; Mr. Duni Chand Puri, ½-inch sheets Nos. 34 $\frac{J}{S. W.}$, 34 $\frac{J}{S. E.}$, 34 $\frac{K}{N. E.}$ and 38 $\frac{O}{N. E.}$ and 1-inch sheets 63 $\frac{F}{14 \& 15}$ and 63 $\frac{J}{2, 3, 6 \& 7}$, left over from 1914-15.

The number of names in the 1-inch sheets of the parts of the United Provinces which came under survey during the year is very great, and the typing of these sheets is therefore a tedious matter.

The following twelve 1-inch sheets left over from 1914-15 with a total area of 3201 square miles were submitted for publication to the head-quarters office during the year:—sheets Nos. 63 $\frac{F}{14, 15 \& 16}$ and 63 $\frac{J}{2, 3, 4, 6, 7, 8, 10, 11 \& 16}$.

The fair drawing of the Nepāl portion of 1-inch sheet, No. 63 $\frac{E}{13}$, and ½-inch sheets Nos. 34 $\frac{J}{N. W., N. E., S. W. \& S. E.}$, is practically complete.

The cost-rate for 1-inch mapping is Rs. 22·1 per square mile, for ½-inch mapping Rs. 2·4 per square mile and for compilation of village boundary editions Re. 0·8 per square mile; the average cost-rate for all being Rs. 3·6 per square mile.

(*b*) Other recess duties comprised the working out of all the rectangular co-ordinates of trijunctions and points for field work in sheets Nos. 63 $\frac{M}{4}$ and 63 $\frac{N}{1, 2, 5 \& 6}$, during season 1916-17, and the compilation and preparation by a small staff, of special editions of 1-inch sheets showing village boundaries. The following fourteen sheets of the village boundary edition were submitted during the year:—sheets Nos. 54 $\frac{M}{15}$, 54 $\frac{N}{14}$, 62 $\frac{H}{12}$, 63 $\frac{A}{1 \& 2}$, 63 $\frac{B}{2 \& 7}$ and 63 $\frac{E}{9, 10, 11, 12, 14, 15 \& 16}$. Eight more sheets are practically complete.

Miscellaneous.—As an attempt to obviate the necessity for traversing for the purpose of providing additional points for detail survey, the fullest possible use was made of the old traverse records of the department; and the co-ordinates of all trijunctions and points occurring in those records were extracted. The success of the experiment was proved by the data thus obtained being found ample for the carrying out of detail survey, and no additional traversing was necessary during the field season. The same exhaustive means of providing a sufficiency of points have been adopted again this year for detail survey during the ensuing

Digitized by Google

field season, and the same successful results are anticipated. As a consequence of this, the services of the traversers and computers of the party were made available during the field season for work in other parties, where they could be more fully employed.

Inspections.—The Superintendent, Northern Circle inspected the recess work of the party in October and June. The Surveyor General accompanied by the Superintendent inspected the recess work of the party in September.

No. 20 PARTY (CANTONMENT).

By A. Ewing.

PERSONNEL.

Provincial Officers.

Mr. A. Ewing, in charge.
" O. D. Jackson, from 1st November 1915.

Upper Subordinate Service.

Mr. Dharmu.

Lower Subordinate Service.

23 surveyors, etc.

During the year under report, the party was employed on the survey of Peshāwar, Rāwalpindi, Bakloh, Jullundur, Sanāwar, Simla (Native Infantry Lines), Kālka, Fort Lockhart, Hangu, Jhelum, Siālkot, Topa and Bannu cantonments on the scale 16 inches = 1 mile; and on that of the bazars of Peshāwar, Rāwalpindi, Bakloh, Jullundur and Bannu on the scale 64 inches = 1 mile. The triangulation and traversing of Rāwalpindi, Fort Lockhart, Hangu and Thal were completed during the year; and Jhelum, Siālkot, Upper and Lower Topa, Chaman and Nīmach have been traversed in advance for season 1916-17. Forty-two fair maps have been sent for publication, sixteen are in hand and fourteen remain to be drawn. These thirty fair maps will be sent for publication by May 1917, and the fair mapping of season 1916-17 will be commenced in March 1917.

The field season commenced in Peshāwar and Jullundur on 1st October 1915, and closed in Rāwalpindi, Topa, Jhelum and Siālkot on 30th September 1916.

The health of the party was good during the year. Some of the surveyors and menials suffered from malarial fever in Rāwalpindi during the months of July, August and September.

Topography.— As Mr. O. D. Jackson, on his transfer to this party, had no previous experience of cantonment survey, Mr. A. Ewing was in charge of the detail survey during the year; but was assisted by Mr. O. D. Jackson and Mr. Dharmu. They are now quite qualified to be placed in charge of sections, and will be employed on more responsible work during season 1916-17.

The accuracy of the work in Peshāwar, Rāwalpindi, Jullundur, Bakloh and Bannu was tested by Mr. A. Ewing by 30·21 linear miles of test lines. Mr. O. D. Jackson, Mr. Dharmu tested the detail survey of Rāwalpindi and Bakloh, Jullundur, Sanāwar, Kālka, Fort Lockhart, Hangu, Thal and Bannu by 28·87 linear miles of test lines. The outturn of detail survey for the year under report is the same as that of last year's; but there is an increase of 5,000 acres contoured during the present season.

The following table gives the outturn and cost of the survey of thirteen cantonments surveyed during the year :—

Scale.	Outturn Acres.	Cost Rs.
16 inches = 1 mile	18,958	26,703
64 " = 1 "	343	3,238

Triangulation.— A sufficient number of stations and intersected points were fixed in Rāwalpindi, Fort Lockhart, Hangu, Thal, Topa and Chaman for the connection of theodolite traversing. The triangulation of Bakloh had to be revised, as the mark-stones fixed by the triangulator in season 1894-95 had been removed. Mr. O. D. Jackson, Mr. Dharmu, and surveyors Gokul Chand and Niaz Ahmad Khan were employed on the triangulation. The cost of the triangulation done during the year is Rs. 2,071.

Traversing.—During the year the traversing of Rāwalpindi, Hangu, Fort Lockhart, Thal, Simla (Native Infantry Lines), Jhelum, Siālkot, Nīmach, Chaman and Topa was completed. The traversing done by the members of the party is :—

	Stations.	Linear miles.
Mr. O. D. Jackson	44 ...	6·98
Mr. Dharmu	108 ...	7·75
Surveyor Gokul Chand	1868 ...	270·60
" Niaz Ahmad Khan ...	658 ...	68·50
" Arthur Francis ...	502 ...	13·80
3 others surveyors	237 ...	13·62
Totals	3417 ...	381·25

The theodolite traversing done during the year is very good, both in angular observations and in chaining. The cost of traversing is Rs. 11,729.

Digitized by Google

About 100 miles of levelling were done in Jullundur, Bannu, Bakloh and Rāwalpindi at a cost of Rs. 3,227.

Recess duties.—Forty-two sheets of fair maps have been sent to Dehra Dūn for publication. The fair drawing of Jullundur, Hangu, Thal, Fort Lockhart, Peshāwar and Bannu is in hand; and the fair sheets of Bakloh and Rāwalpindi are remaining to be drawn. The sheets that are in hand will be sent for publication by December, and the fair drawing of Bakloh and Rāwalpindi will be completed by May 1917. The fair drawing was done under the supervision of Mr. A. Ewing, who examined all the sheets before sending them for publication. The cost of the fair drawing for the year is Rs. 6,515.

Programme for season 1916-17.—The detail survey of Rāwalpindi cantonment is to be completed and the entire detail survey of those of Jhelum, Siālkot, Topa, Drazinda, Jandola, Jatta, Zām, Chitrāl, Upper Drosh and Lower Drosh, is to be carried out. Nasīrābād, Deoli and Jhānsi cantonments will be triangulated and traversed in advance for purposes of detail survey in 1917-18. As it will be impossible to predict what the political condition will be on the Frontier when the survey of Chitrāl, Upper Drosh, Lower Drosh, Drazinda, Jandola, Jatta and Zām has to be done, there may be changes in the programme.

Inspections.—The party was inspected by the Superintendent Northern Circle in February 1916 at Rāwalpindi and Peshāwar.

RIVERAIN DETACHMENT.

By Rai Sahib Maya Das Puri.

The field operations in connection with riverain and other surveys for the Punjab Government were commenced on the 18th October 1915, and were finally brought to a close on the 7th August 1916. The head-quarters of the detachment remained at Campbellpore throughout the year.

PERSONNEL.

Provincial Officer.

Rai Sahib Maya Das Puri, in charge.

Upper Subordinate Service.

Mr. Paras Ram.
" Lakshmi Dutt Joshi, from the 20th October 1915.
" Vidya Dhar Chopra.

Lower Subordinate Service.

74 Surveyors, etc.
6 Naib Tahsildars and Kanungoes, etc.

Mr. Lakshmi Dutt Joshi, Sub-Assistant Superintendent, joined the detachment on the 29th October 1915, and was employed on the Lahore Cantonment boundary survey, Kāngra traversing, the Indus riverain main circuits in district Dera Ghāzi Khān and Bahāwalpur State, and computations.

Mr. Vidya Dhar Chopra, Sub-Assistant Superintendent, supervised 4 traversers, and was put on the riverain traverse on the Sutlej, and the Beas (districts Ambāla and Kāngra), the Indus main circuits, computations, and checking stores.

Munshi Ganda Singh, *Nāib Tahsildār*, remained in charge of a field camp in districts Simla and Kāngra; and assisted in computations, plotting, and vernacular correspondence, etc.

Surveyor Ishwar Singh continued to look after the Kāngra field work, and the road survey; and trained new hands.

The Riverain Surveys.—The following tables (1), (2) and (3) give full detail of the riverain work completed during the year:—

(1) Out-door work.

Names of Rivers, Districts and Scales.	Straight length in miles.	Main-circuit.			Minor Traverse for Detail Survey.				Base Lines.			Remarks.
		Number of square miles.	Number of linear miles.	Number of theodolite stations.	Number of square miles.	Number of linear miles.	Number of theodolite stations.	Number of villages.	Number of corners.	Number of squares.	Area in square miles.	
Sutlej River. District Ambāla, Scale $\frac{1}{2290}$.	Nil	...	...	...	45·0	358	1890	71	...	...	...	
Beas and Chakki Rivers. Districts Kāngra, Hoshiārpur and Gurdāspur, Scale $\frac{1}{2300}$.	Nil	...	...	...	55·0	393	2051 †239	48	162	54	100·0	* In addition to these 48 traverse stations were demarcated with permanent mark-stones.
Indus River. District Dera Ghāzi Khān and Bahāwalpur State, Scale 220 feet = 1 inch	52	459	155	255 †6	...	...	...	...	...	...	...	† These are intersected points.
Total	52	459	155	261	100·0	751	4170	119	162	54	100·0	

Digitized by Google

(2) OFFICE WORK DONE FOR THE CADASTRAL SURVEYS OF RIVERAIN ESTATES.

Name of river.	Name of district.	Scale of *masāvis*.	Number of plotted *masāvis* showing traversed points.	Number of compiled *masāvis* showing riverain boundaries.	Number of sheets traced for the use of Settlement Officers on scale 4 inches to a mile.	Number of 4 inch sheets on which new work was plotted.
Sutlej ...	Ambāla ...	$\frac{1}{2280}$	302	89	5	5
Beās ...	Kāngra ...	$\frac{1}{2300}$	550	53	3	3
	Total ...	...	852	142	8	8

Besides these, 108 miscellaneous traces were prepared.

(3) OFFICE WORK DONE FOR THE 4-INCH COMPILATION OF RIVERAIN BOUNDARIES.

Names of rivers.	Names of series.	Number of sheets compiled.	Number of sheets typed.	Number of sheets finally examined and completed
Rāvi ...	Montgomery	...	11	...
Jumna ...	Ambāla / Sahāranpur and Karnāl	...	5	...
Beās ...	Kāngra / Hoshiārpur	5	...	...
	Total ...	5	16	...

In addition to these, 504 *masāvis* of 106 *tikās* of districts Kāngra and Hoshiārpur were reduced with a pentagraph to the scale 4 inches to a mile for the Beās compilation.

The Kāngra Special Survey.—This survey was started on 18th October 1915 under the usual conditions in continuation of the last season's programme. 2162 linear and 300 square miles of the district area, were traversed, and triangulated; and 12067 stations were fixed with theodolite in 575 *tikās* (sub villages). 1992 plotted *masāvis* of 260 *tikās* on the scale 20 karams (one karam = 57·5 inches) to an inch, 1520 *masāvis* of 511 *tikās* on the scale 40 karams to an inch, 30 *masāvis* of 21 *tikās* on the scale 80 karams to an inch, and 17 traces on the scale 4 inches = 1 mile were supplied to the Settlement Officer, Kāngra. Besides these, 56 miscellaneous traces were prepared, and all the traverse stations marked during the year were plotted on 22 four-inch sheets.

The work was based on the triangulation done by the old No. 18 Party (Himālaya), and this necessitated the admission, in some cases, of heavier linear correction than 1 in 500 in closing the traverses. This work is practically finished. Only the computations of 414 points, the plotting of 230 *tikās*, and the completion of the computation records remain to be done. This, it is hoped, will be finished early during next season. The riverain work done in the Kāngra district on the Beās is given under head ***Riverain Surveys.***

The Simla Survey.—This survey was commenced in the Kotgarh tract on the 2nd October, and was closed on the 30th November 1915. 1066 linear, and 15 square miles were traversed, and triangulated; and 1153 stations were fixed with theodolite. 256 plotted *masāvis* of 70 villages on the scale 40 karams (one karam = 54 inches) to an inch and 2 four-inch sheets were traced, and supplied to the Settlement Officer, Simla. Besides these 4 other miscellaneous sheets were prepared, and all the traverse stations marked during the year were plotted on 1 four-inch sheet. The work is finished but the computation records have yet to be completed.

The Khaur Special Survey.—At the special request of the Deputy Commissioner, Attock (Campbellpore), the Khaur special survey was taken up for the Attock Oil Company. Four

Digitized by Google

squares, joining one another, of one square mile each were demarcated with theodolite at certain bearings, and distances supplied by the company with reference to Khaur H.S. 45 linear miles were traversed and 173 stations laid out with theodolite. The area (4 square miles) was then plane-tabled on the scale 8 inches to a mile, showing detail. The hills were sketched, and no regular contours were shown. The map was then traced, fair drawn and supplied to the company within three months. The cost of this work was Rs. 1365, which was recovered from the Attock Oil Company.

The Kāngra Road Survey.—This survey was carried out in continuation of the last year's programme, with the object of avoiding boundary discrepancies as compared with the Settlement maps. 41·6 miles of road, from mile No. 7 to mile No. 48·6, were surveyed. 556 points were fixed with theodolite, and 44 linear miles traversed. 63 sheets of the last year's work, and copies of the *khasrās* (records of rights) were completed and supplied to the Executive Engineer, Provincial Division, Kāngra.

The traverse field books are the only records of this work which have been retained departmentally.

The work surveyed this year is being plotted, and the sheets will be supplied to the Executive Engineer during the coming season.

The Lahore Cantonment Survey.—With a view to test the area of grass land, the Lahore Cantonment boundary survey was undertaken at the request of the Cantonment Magistrate, Lahore. The work was based on the old No. 1 Party (Punjab)'s traverse values. In all, 22 linear miles, containing 70 theodolite stations, were traversed, in 1472 acres; and the boundaries of 8 plots of 1190 acres surveyed. A trace of the map, on the scale of 12 inches to a mile, showing the boundaries, areas, etc., was supplied to the Cantonment Magistrate, Lahore.

The nature of country under survey.—The riverain part was in places sandy, marshy, broken, raviny, and was covered with shrubs, and high grass in the beds of the rivers. Portions above the high banks were well cultivated, and wooded. On the Indus they were flat; and on the Sutlej, and the Beās partly hilly, and partly open plain. The Kāngra tract varied, it included the steep, and wooded hills on the north; and the undulating cultivated plains, with detached rocky outcrop, towards the south.

The Kotgarh (Simla district) area consisted of high densely forest-clad hills, mostly forest reserves, from 2600 to 8700 feet high above the sea level, the higher hills generally covered with snow during winter, and cultivated here and there.

The Khaur ground was in parts bare and hilly, and in parts cultivated.

The Lahore Cantonment land was open and flat, and well cultivated.

The health of the detachment was good throughout the year.

The Kāngra and the Simla district surveys, and the riverain traversing on the Sutlej and the Beās, were connected with Dinalādh H.S. XX, Tilhārā H. Staff, Bhulanā H. Staff, Darot h.s., Mainpur H. Staff, Thabkaur s., Paderoā h.s., and Tāpa H. Staff, and 80 triangulated stations of the old No. 18 Party (Himālaya).

The Indus main circuits were connected, and based on the values of Dago T.S. LXXVI, Shāhpur T.S. LXXIII, Lanjiwār T.S. LXXXI, Dāowālā T.S. LXII, Sarhīn T.S. LXVIII, Kahīrī T.S. LXXI, and Mīrapur T.S. LXIX, of the Great Indus Series.

The average errors in the various classes of work were as follows:—

(1) Riverain Surveys:—

(*a*) Base lines 1·18 feet per corner when compared with the theoretical values.

	Angular error per station in seconds.	Linear error in links per ten chains.
(*b*) Main circuits	3·47	0·22
(*c*) Sub traverses	7·78	0·70
(2) Kāngra traversing and triangulation	9·81	1·06
(3) Simla traversing and triangulation ...	1·61	0·40
(4) Khaur Special Survey	4·51	0·21
(5) Kāngra Road Survey	6·47	1·42
(6) Lahore Cantonment Survey ...	8·57	0·90

Digitized by Google

The total expenditure of the detachment from the 1st October 1915 to 30th September 1916 was Rs. 76,522 as detailed below :—

		Rs.
1.	Riverain Surveys including the Kāngra riverain work on the Beās	28,706
2.	Kāngra District Survey excluding the riverain area on the Beās	43,881
3.	Simla Survey	3,033
4.	Kāngra Road Survey	250
5.	Lahore Cantonment Survey ...	652

The cost-rates per square mile come to Rs. 146·2, and Rs. 209·2, for the Kāngra District, and the Simla Survey respectively. They are slightly higher than those of previous season. In the case of the former this is due chiefly to the arrears of plotting and computations, and partly to the more rugged and difficult nature of the ground. In that of the latter, it is due to 80 stations per square mile having been fixed, as compared with 57 of the last year.

The detachment was inspected by the Superintendent, Northern Circle, on the 25th and the 26th February 1916.

SIMLA SURVEY DETACHMENT.

By C. E. C. French.

Field work closed in Simla at the end of March 1916, when the detachment proceeded to Mussoorie to complete the fair drawing.

Personnel.

Provincial Officers.

Mr. C. E. C. French, in charge.
" F. C. Saint, from 27th October 1915 to 30th April 1916.

Upper Subordinate Service.

Mr. Imam Din.
" J. P. Vastav (Probationer), from 29th October 1915 to 31st March 1916.
" Ghulam Hasan (Probationer), from 29th October 1915 to 31st March 1916.
" A. A. S. Matlub Ahmad (Probationer), from 29th October 1915 to 31st March 1916.
" D. R. Vohra (Probationer), from 29th October 1915 to 31st March 1916.

Lower Subordinate Service.

7 Surveyors, etc.

Field Operations.—The topography of 1050 acres in Simla, on a scale of 125 feet to 1 inch, was completed at an aggregate cost of Rs. 16,638.

No triangulation or traversing was done during the year.

Recess Duties.—(*a*) 14 fair sheets, out of a total of 32, have been despatched for publication. The remainder will be completed by the end of November 1916. These sheets have been drawn on a scale of 125 feet = 1 inch for the production of two separate sets of maps on scales of 150 and 220 feet to 1 inch. The former to meet general requirements in connection with Colonisation and Improvement projects; the latter to form a combined map for purposes of illustrating Water-works, and Sewage Systems, in Simla. The aggregate cost of mapping is Rs. 7456, or Rs. 2·0 per acre.

(*b*) A proposed survey of 5·3 square miles (or 3392 acres) of country, illustrating a dispute between Patiāla and Koti States, was abandoned for reasons of expense; and, instead, a pentagraph enlargement from existing 2-inch surveys was supplied to the Assistant Political Officer in January 1916.

(*c*) The large-scale data of the Simla Survey have been utilised in the preparation of a Guide map of Simla, to be published on the scale of 8 inches = 1 mile. The commencement of the fair mapping is pending receipt of blue print reductions from Calcutta.

Digitized by Google

SOUTHERN CIRCLE.

(*Vide* Index Maps 2 and 5).

Summary.—This Circle was under the superintendence of Colonel T.F.B. Renny-Tailyour, C.S.I., R.E. throughout the year and consisted of Nos. 5, 6, 7 and 8 Parties, No. 4 Drawing Office and the Training Section.

During the year 17,243 square miles of detail survey and 31,680 square miles of triangulation have been completed.

The detailed survey consists of :—

9,886	square	miles	of	½-inch survey.
6,488	„	„	„	1-inch survey.
715	„	„	„	1-inch supplementary survey.
30	„	„	„	1½-inch survey.
124	„	„	„	2-inch survey.

Owing to the shortage of supervising officers on account of the war, the detail survey was considerably curtailed. Nos. 6 and 7 Parties took the field with a full strength of surveyors but the majority, including the head-quarters, of Nos. 5 and 8 Parties remained at Bangalore throughout the year and were principally employed on the fair drawing of ½-inch sheets compiled from 1-inch sheets.

The Training Section carried out detail survey on the 2-inch scale in sheet $57\frac{G}{10}$. 19 pupil surveyors received instruction in topographical surveying.

Magnifying glasses, attached to stands, were obtained from the Mathematical Instrument Office and were usefully employed by some of the draftsmen in this Circle when fair drawing on blue prints, most draftsmen are able to draw under a magnifying glass without any previous practice. This method is particularly helpful to draftsmen whose sight is failing as well as in cases when the fair drawing is for the ½-inch or ¼-inch scale on blue print reductions with intricate detail or contours.

The following work was undertaken in the Photo-Zinco Section of No. 4 Drawing Office :—

Reproductions	47
Enlargements	113
Reductions	123
Sheets vandyked	216
Copies printed	4,850

No. 5 PARTY (BERÂR, CENTRAL INDIA AND CENTRAL PROVINCES).

By J. O' B. Donaghey.

PERSONNEL.

Provincial Officers.

Mr. J. O' B. Donaghey, in charge.
„ F. C. Pilcher.

Upper Subordinate Service.

Mr. Damodar Khadilkur.

Lower Subordinate Service.

19 Surveyors, etc.

This party took the field in reduced strength and completed the detail survey on the 2-inch scale of scattered reserved forest areas in sheets $55\frac{C}{8,9,10,11,12,13,14}$, and also carried out a 4-inch plane-table skeleton boundary survey of the outer boundaries of the surveyed reserved forests. The party also completed the triangulation of sheets $55\frac{B}{3,4,7,8,11,12,15,16}$, $55\frac{F}{3,4,6,7,10,11}$.

The areas surveyed consist of wooded hills and the country triangulated comprises forest-clad hills and undulating cultivated areas.

The field season opened on the 25th October 1915 and closed on the 26th April 1916. The head-quarters of the party remained at Bangalore throughout the year.

The health of the party was good. One surveyor died of fever during the recess season.

Topography.—The areas surveyed comprise five scattered reserved forests consisting of hills with open forest.

Mr. Pilcher, before commencing his triangulation, attended to the preliminary field arrangements for the 2-inch survey and the 4-inch boundary survey, which were carried out by two surveyors under direct orders of the party head-quarters. No difficulty was experienced.

The total area surveyed on the 2-inch scale was 64 square miles, the average monthly outturn per man was 6·6 square miles and the cost-rate per square mile was Rs. 43·0.

Triangulation.—The nature of the country, which lies along both banks of the Narbadâ river, is hilly and undulating; all the hills and portions of the undulating country are forest-clad interspersed with open undulating areas.

Digitized by Google

Mr. Pilcher completed an area of 3,302 square miles in sheets 55 $\frac{B}{3,4,7,8,11,12,15,16}$, 55 $\frac{F}{6,7,10,11}$ and Mr. Damodar Khadilkur, who was instructed in triangulation by Mr. Pilcher in the field, completed an area of 551 square miles in sheets 55 $\frac{F}{3,4}$. Sheets 55 $\frac{F}{1,2,5,8,9,12,15,16}$ and the northern half of sheet 55 $\frac{F}{13}$ were reconnoitred by Mr. Pilcher, and it was found that the triangulation already existing in these areas will be sufficient for topographical purposes.

The total outturn was 3,853 square miles and the cost-rate per square mile was Rs. 3·2.

Recess Duties.—The majority of the party was employed throughout the year on fair drawing for ½-inch sheets compiled from 1-inch sheets.

The fair drawing was carried out by a drawing section which was supervised by Mr. Donaghey during the field season and was subsequently placed under Messrs. Pilcher and Damodar Khadilkur. The fair sheets are being drawn on ¾-inch blue print reductions, on drawing paper, of the component 1-inch sheets. Sheets 55 $\frac{J}{N.E.}$, 55 $\frac{M}{N.E.}$, 64 $\frac{A}{N.W., S.E.}$ have been completed and submitted for publication, sheets 54 $\frac{L}{S.W.}$, 54 $\frac{P}{S.E.}$, 55 $\frac{I}{S.W.}$, 64 $\frac{A}{N.E.}$ are practically completed and sheets 54 $\frac{P}{S.W.}$, 55 $\frac{D}{N.W.}$, 55 $\frac{I}{S.E.}$, 55 $\frac{K}{N.E., S.E.}$ are in hand.

The total area fair drawn is 8,725 square miles and the cost-rate per square mile is Rs. 1·7.

The computations of the triangulation were not completed owing to the reduction in the number of officers due to the war. In 1916-17 the party will take the field again in reduced strength, and the party staff left in recess quarters will complete all arrears of computations before the next recess season.

Triangulation charts 54.L and 55.N are being brought up to date, and 55.G is in hand.

No. 6 PARTY (BOMBAY AND HYDERĀBĀD).

By P. R. Anderson.

This party completed the detail survey on the 1-inch scale of sheets 47 $\frac{M}{3,4,7,8}$ and on the ½-inch scale of sheets 47 $\frac{N}{N.E.}$, 56 $\frac{B}{N.W., S.W., N.E., S.E.}$, 56 $\frac{F}{N.W., S.W., N.E., S.E.}$, except that the areas of Bombay in sheets 47 $\frac{N}{9,10}$, 56 $\frac{B}{3,4}$ were surveyed on the 1-inch scale and the areas of reserved forests in sheets 56 $\frac{F}{14,15}$ were surveyed on the 1½-inch scale. The party also undertook the triangulation for the 1-inch, ½-inch and 1½-inch scales in sheets 56 $\frac{C}{1 \text{ to } 16}$, 56 $\frac{G}{1 \text{ to } 10,\ 13 \text{ to } 16}$, 56 $\frac{H}{1,5,6}$, 56 $\frac{K}{1 \text{ to } 16}$.

The general nature of the country is varied. It consists of rocky hills, and of well cultivated plains separated by flat-topped hills dotted over by scattered patches of jungle or by a series of disconnected rocky hillocks.

The field season opened on the 25th October 1915 and closed on the 22nd April 1916. The field head-quarters was at Ahmadnagar.

The health of the party was on the whole good. Two menials died.

Personnel.

Imperial Officer.

Major L. C. Thuillier, I. A., in charge up to 25th May 1916.

Provincial Officers.

Mr. P. R. Anderson, from 1st to 25th May 1916, and in charge from 26th May 1916.
" P. Kennegy.
" E. A. Meyer.
Khan Bahadur Haji Abdul Rahim.
Mr. F. B. Kitchen.
" Munshi Lal, B. A.
" M. S. Ganesa Aiyar.
" J. C. St. C. Pollett.
" K. S. Gopalachari, B. A.

Upper Subordinate Service.

Mr. Eknath Battu.
" Ram Narayan Hastir.
" Nabidad Khan, from 13th October 1915.
" Masud Khan, promoted from 1st July 1916.

Lower Subordinate Service.

41 Surveyors, etc.

Topography.—The country surveyed comprises the basins of the Godāvari and Mānjra rivers, a portion of the Bālāghāt range of hills and the plateau enclosed by the range and its two spurs, the one forming the watershed between the Sīna and Mānjra and the other that between the Mānjra and Godāvari rivers. The basins of the Godāvari and Mānjra cover open, undulating and well cultivated country. The Bālāghāt is an intricate stony range of hills varying from 3 to 6 miles in width and running due east and west right through the northern portion of the work. The Bālāghāt plateau consists of narrow valleys separated by flat-topped hills, covered here and there by patches of jungle.

The work was divided among four camps as follows :—

No. 1 Camp.—Under Mr. Meyer assisted by a senior surveyor with Mr. Nabidad Khan and 10 junior surveyors carried out detail survey on the 1-inch scale in sheets 47 $\frac{M}{3,4,7,8}$, 56 $\frac{B}{3,4}$ and on the ½-inch scale in sheet 56 $\frac{B}{S.W.}$.

Digitized by Google

No. 2 Camp.—Under Mr. Haji Abdul Rahim with 6 surveyors, assisted towards the end of the field season by surveyors from the other camps, carried out detail survey on the ½-inch scale in sheets 56 $\frac{F}{\text{N. W. (E. half), S. W., N. E., S. E.}}$ and on the 1½-inch scale of reserved forest areas in sheets 56 $\frac{F}{14, 15}$.

No. 3 Camp.—Under Mr. Kitchen with 8 surveyors carried out detail survey on the 1-inch scale in sheets 47 $\frac{N}{9, 10}$ and on the ½-inch scale in sheets 47 $\frac{N}{\text{N. E.}}$, 56 $\frac{B}{\text{N. W.}}$.

No. 4 Camp.—Under Mr. Munshi Lal with 6 surveyors carried out detail survey on the ½-inch scale in sheets 56 $\frac{B}{\text{N.E., S.E.}}$, 56 $\frac{F}{\text{N. W. (W. half)}}$.

Two senior surveyors were also employed entering cultivation limits in sheets 56 $\frac{A}{\text{N. E., S. E.}}$, 56 $\frac{E}{\text{S. W., S. E.}}$, these limits were omitted, according to the rules then in force, when the detail survey on the ½-inch scale in these sheets was undertaken.

As it was considered advisable to start all the junior surveyors, who were more or less still under instruction, on the 1-inch rather than on the more difficult ½-inch scale, they were employed, during the greater part of the field season, on the 1-inch scale in No. 1 Camp under Mr. Meyer who was assisted by a senior surveyor as an assistant instructor. Towards the end of the field season the more promising surveyors were distributed among the other camps and employed on the ½-inch scale. Not only did the country surveyed prove peculiarly fitted for training but it was found that the individual outturn and technical progress was very satisfactory, each man getting that help and instruction which it would have been impossible for him to get had he been attached to an ordinarily constituted camp and allowed to take his chance with the senior men.

A total area of 11,177 square miles was surveyed. The outturn of the ½-inch, 1-inch and 1½-inch surveys was 9,886, 1,261 and 30 square miles respectively, the average monthly outturn per man was 83·5, 23·6 and 8·5 square miles respectively and the cost-rate per square mile was Rs. 4·5, Rs. 10·5 and Rs. 66·3 respectively. The cost-rate of the 1½-inch survey being so exceptionally high is due to the fact that the areas of the reserved forests are small and scattered with intricate boundaries. Areas of 9,886, 284 and 30 square miles of ½-inch, 1-inch and 1½-inch surveys respectively were in Hyderābād.

Triangulation.—The country triangulated consists, for the most part, of populous valleys separated by flat-topped hills and, except a small area in sheet 56 $\frac{G}{15}$, was not densely wooded.

Mr. Kennegy completed an area of 1,700 square miles in sheets 56 $\frac{C}{1, 2, 3, 5, 6, 7}$, Mr. Ganesa Aiyar 3,691 square miles in sheets 56 $\frac{G}{1, 2, 3, 4, 5, 6, 7, 8, 12, 16}$, 56 $\frac{H}{1, 5, 6}$, Mr. Pollett 2,458 square miles in sheets 56 $\frac{K}{1, 2, 3, 4, 5, 6, 7, 8, 12}$, Mr. Gopalachari 1,196 square miles in sheets 56 $\frac{G}{9, 10, 13, 14, 15}$, Mr. Eknath Battu 2,079 square miles in sheets 56 $\frac{K}{9, 10, 11, 12, 13, 14, 15, 16}$ and Mr. Ram Narayan Hastir 2,837 square miles in sheets 56 $\frac{C}{4, 8, 9, 10, 11, 12, 13, 14, 15, 16}$.

The country on the whole was not difficult to triangulate, but considerable difficulty was experienced in selecting stations far enough apart, as the hills were of a uniform height.

The total outturn was 13,961 square miles and the cost-rate per square mile was Rs. 3·7. Areas of 12,707 and 200 square miles for the ½-inch and 1½-inch scales respectively were in Hyderābād.

Recess Duties.—The fair drawing was divided among four sections, as follows:—

No. 1 Section.—Under Mr. Meyer, 1-inch sheets 47 $\frac{M}{4, 7, 8}$ and ½-inch sheets 47 $\frac{N}{\text{N.E.}}$, 56 $\frac{B}{\text{S. E.}}$.

No. 2 Section.—Under Khan Bahadur Haji Abdul Rahim, ½-inch sheets 56 $\frac{F}{\text{S. W., N. E., S. E.}}$.

No. 3 Section.—Under Mr. Kitchen, 1-inch sheets 47 $\frac{M}{3}$, 47 $\frac{N}{9, 10}$, 56 $\frac{B}{3, 4}$ and ½-inch sheets 56 $\frac{B}{\text{N.W., S.W.}}$.

No. 4 Section.—Under Mr. Munshi Lal, ½-inch sheets 56 $\frac{B}{\text{N. E.}}$, 56 $\frac{F}{\text{N. W.}}$.

All the sheets were completed to margin with the exception of the 1-inch sheets 47 $\frac{N}{7, 10}$, 56 $\frac{B}{3, 4}$ which only contain the areas of Bombay falling in them. No. 4 Drawing Office lent some draftsmen to assist the work, and the fair drawing should be practically completed by the end of the recess season.

The total area of fair drawing was 11,317 square miles (10,054 square miles for the ½-inch and 1,263 square miles for the 1-inch scale) and the cost-rate per square mile was Rs. 1·8. An area of 140 square miles was fair drawn for both the ½-inch and 1-inch scales. Areas of 9,943 and 257 square miles of fair drawing for the ½-inch and 1-inch scales respectively were in Hyderābād.

Digitized by Google

Computations sufficient for the work during the next field season were completed, and the balance will be completed during the field season.

Triangulation charts 47.M, 55.D, 56.A and 56.E are in hand.

Miscellaneous.—There are very few *pukka* roads in the Hyderābād State and the cart tracks are only fair weather roads, as the black cotton soil makes wheel traffic next to impossible, even after only a few showers. Besides this the cart owner is invariably a cultivator, who uses his cart merely as a means of gathering in his produce and getting it to market. He uses his plough or *moat* bullocks as draught animals and is naturally very reluctant to do without them during his busiest time. He will with persuasion carry things to the next village but no further. Under these circumstances it was found necessary to supply the camp officers and triangulators, who have long marches to make, with camel transport. The rate for camels in the Hyderābād State is prohibitive. It was therefore found expedient to get the party camels from the Central Provinces. Much difficulty is experienced with jāgīrs. These are more or less independent of the districts, to which they are assigned, and, without *parwanas* from their owners, it is impossible to get local assistance. There are very few British post offices in the State, and special arrangements have to be made for the distribution of money. The Nizām's railways conduct all transactions in *halli sikka* coin, and, as the exchange is always varying and the railway rate invariably differs from the market rate, there is some trouble in adjusting accounts. Game is very strictly preserved. Shooting in Hyderābād forests is entirely prohibited. Custom dues are levied by the State, but exemption from these can be obtained by applying for it.

No. 7 PARTY (MADRAS).

By W. M. Gorman.

The party completed the 1-inch detail survey of sheets 57 $\frac{O}{1,2,3,4,5,6,7,8,11,12,15,16}$, 57 $\frac{P}{9,10,13,14}$, 66 $\frac{C}{3,4,7,8}$, 66 $\frac{D}{1,2,3,4,5}$ with the exception of small areas of reserved forests and the district of Madras in sheets 57 $\frac{O}{4,5,15}$ and 66 $\frac{C}{8}$ respectively which were surveyed on the 2-inch scale.

Personnel.

Provincial Officers.

Mr. W. M. Gorman, in charge.
" S. F. Norman.
" H. B. Simons, from 30th June 1916.
" V. W. Morton.
" C. West.
" H. H. P. Butterfield.
" N. S. Harihara Iyer.

Upper Subordinate Service.

Khan Sahib Abdul Hakk.
Mr. Kodandera Mandanna.
" P. S. Vengusvami.
" Shib Lal.
" H. Narasimhamurti Rao.
" Shaikh Muhammad Salik, promoted from 1st July 1916.
" E. N. Natesan, B.A.
" Pulin Behari Roy.
" Jitendra Mohan Mukerji.

Lower Subordinate Service.

40 Surveyors, etc.

The Eastern Ghāts, a confused hill system with abrupt rises and falls and cultivated low expanses succeeding disjointed ranges in rhythmical order, formed the western limit of the work, these finally merge and are lost in one extensive cultivated plain to the sea coast, to start again further south at St. Thomas's Mount in detached small ridged or conical hills to be again lost in the low land. The fairly high hills of the Eastern Ghāts known locally in Cuddapah as the Pālkondas are forest-clad and are mostly reserved forests, the Kārvetnagar or low hills in Chittoor district are more or less bare and rocky.

The party took the field on the 1st November 1915, reached camp head-quarters at Arkonam on the same day, and returned to recess at Bangalore by the 30th April 1916, with the exception of the triangulators and one surveyor doing the town of Madras, who reached on the 20th and 23rd June 1916 respectively. The north-east monsoon, which was generally a failure at its start, broke in earnest about the beginning of November and lasted practically throughout the month delaying progress of work considerably.

The health of the party throughout was very good. First class surveyor Y. Narayanasvami Nayadu succumbed at Bangalore on the 14th March 1916, and surveyor Shankar Balaji Mandhre went on medical leave during the field season.

Topography.—The country surveyed stretches from the fairly high hills of the Eastern Ghāts on the west (locally known as the Pālkondas in Cuddapah and the Tirupati and Kārvetnagar hills in Chittoor district), in a succession of cultivated valleys and disjointed ranges further east which finally merge into the plains of Madras, to the sea coast. In the former, mostly covered with reserved forests, hill features are more regular and less confused

Digitized by Google

than in the latter, where continuity is lost in a succession of detached hill ranges, mostly devoid of forest growth except for a fringe of thorny growth, with low and undulating cultivated expanses in between, studded with numerous tanks and a large number of wells to supplement the former. The most conspicuous and notable of these detached hill ranges is the Nagari hills with high and precipitous cliffs standing boldly out above the plains as a landmark for miles around. On the summit of its highest point called Nagari Nose, 2,814 feet, lights were burnt in John Company's time to guide ships into the Madras harbour. The country further east and on to the sea coast extends in one unbroken plain, relieved by small ridged or conical hills starting at St. Thomas's Mount running south and forming a continuation of the Eastern Ghāts. The capital of the Madras Presidency and many big towns and other places of historical interest fall in the area. The country is well populated and highly cultivated. Palmyra groves and other trees are abundant and help to shelter many thriving villages. A feature of the sea coast is the heavy growth of casuarina. The Pālār, Arni, Cooum (Kūvam), Adyar, Swarnamukhi Ponnaiyār and many other minor rivers augmented by innumerable tanks help to drain and irrigate the country.

The work was distributed as follows :—

No. 1 Camp.—Under Mr. Butterfield with an average of 5 surveyors completed an area of 790 square miles of 1-inch survey, 652 square miles of 1-inch supplementary survey and 2 square miles of 2-inch survey of reserved forests in sheets 57 $\frac{O}{1, 2, 3, 5, 6}$.

No. 2 Camp.—Under Mr. Norman assisted by surveyor Y. Narayanasvami Nayadu as an instructor with 11 surveyors and with the help of 2 surveyors from other camps surveyed an area of 1,388 square miles of 1-inch survey, 49 square miles of 1-inch supplementary survey and 10 square miles of 2-inch survey of reserved forests in sheets 57 $\frac{O}{4, 7, 8, 11, 12}$.

No. 3 Camp.—Under Mr. West with 9 surveyors surveyed an area of 1,253 square miles of 1-inch survey, 14 square miles of 1-inch supplementary survey and 48 square miles of 2-inch survey of reserved forests and of the town of Madras in sheets 57 $\frac{O}{15, 16}$, 66 $\frac{C}{3, 4, 7, 8}$.

No. 4 Camp.—Under Mr. Abdul Hakk with 11 surveyors completed an area of 1,796 square miles of 1-inch survey in sheets 57 $\frac{P}{9, 10, 13, 14}$, 66 $\frac{D}{1, 2, 3, 4, 5}$.

The 2-inch reserved forests surveyed consist of small scattered areas situated in low and rocky hills with a stunted growth of thorny shrub, grass and low bush. No difficulty was experienced in the survey and interpolation was possible throughout. The boundaries were checked with notifications and rough traces and maps supplied by the forest authorities during the time of survey. For the survey of the town of Madras a 2-inch blue print of the survey of the town as done by the Madras Revenue Survey was obtained and inked up in black and on measurement was found to be less than its denoted scale. Proper measurements were computed and a blue enlargement to the 2-inch scale on mill board was supplied by the Photo-Zinco Section, Southern Circle. On receipt, to enable plotting of traverse data utilised in the former survey, rectangular coordinates of graticule corners were computed in terms of the Madras Revenue Survey origin. The above data and a few trigonometrical points, supplemented by others by means of triangulation, helped the surveyor to begin and close his plane-table traverses carried throughout the work. The work done by the Madras Revenue Survey proved generally useful, helpful and accurate. The area of the town or district of Madras is nearly 28 square miles to complete which, surveyor C. Venkatasvami took 199 working days in a field season of 8 months and 3,656 traverse fixings.

The 1-inch survey was considerably helped by 1-inch prints of maps supplied by the Madras Revenue Survey. When these prints contained very little or no zamīndāri area in which detail given was meagre or none at all, direct blue prints on mill and Bristol boards were obtained from the Photo-Zinco Section as well as from the Madras Revenue Survey Office, Madras. Prints embracing zamīndāri area were not availed of in the manner above noted but were transferred in blue by the surveyors as the work progressed but proved unreliable and of no value. The work of the Madras Revenue Survey proved again very accurate and helped considerably the progress of the party. In the coast sheets, where trigonometrical points were few and far between, trijunctions of the Madras Revenue Survey were utilised as starting and closing points of plane-table traverses. In the same sheets a difficulty about heights was experienced but was overcome by running a series of theodolite heights from G. T. Bench-marks outside the work and carried on further and throughout the work by a series of clinometric heights.

The 1-inch supplementary survey was obtained from the existing 4-inch published maps of reserved forests, previously surveyed, by blue print reductions to the 1½-inch scale, on

Digitized by Google

which all detail was inked up in black and all symbols made to conform to the latest existing sheet of symbols and hill features indicated thereon. The prints on completion were pasted in position on a projected and plotted 1½-inch sheet by means of trigonometrical points common to both and the whole was reduced to the 1-inch and printed on Bristol boards, etc. The work was supplemented where necessary and brought up to the standard of surveys and contoured by numerous heights and was found very correct. The country presented no difficulty in survey. Coolie transport, which had to be obtained from villages far distant, retarded work to a certain extent and might have been worse had the Forest officials not helped to their utmost.

The full programme of the party, amounting to 6,002 square miles, was completed. The outturn of the 1-inch survey, of the 1-inch supplementary survey and of the 2-inch survey was 5,227, 715 and 60 square miles respectively, the average monthly outturn per man was 31·8, 49·1 and 4·9 square miles respectively and the cost-rate per square mile was Rs. 8·5, Rs. 6·5 and Rs. 65·8 respectively.

Triangulation.—The triangulation completed embraces the eastern slopes of the Nallamalais in the north, the prominent hill ranges known as the Velikondas, mostly reserved forests with open jungle and extending over more than three quarter of the area in the west, together with minor disjointed hill ranges 5 to 6 miles in length, for the most part bare and rocky, the whole known as the Eastern Ghāts. The remaining part of the country to the east of the main hill ranges consists of flat and undulating ground with isolated rocky hills well distributed, standing out of the plains. The country is generally open and easy of survey except near and along the sea coast where the ground is covered with palmyra and casuarina groves and other trees. Main roads and village cart tracks throughout the area are numerous. In the hills villages are few and a scarcity of water is felt from April onward to the break of the south-west monsoon.

Mr. Morton completed an area of 2,292 square miles in sheets 57 $\frac{M}{1, 2, 3, 4, 5, 6, 7, 8}$, Mr. Harihara Iyer 1,896 square miles in sheets 57 $\frac{M}{9, 10, 11, 13, 14, 15}$, 57 $\frac{N}{7}$, 66 $\frac{A}{3}$, Mr. Kodandera Mandanna 2,235 square miles in sheets 57 $\frac{N}{1, 2, 3, 4, 5, 6, 7, 8}$, Mr. Shib Lal 2,283 square miles in sheets 57 $\frac{N}{7, 8, 10, 11, 12, 14, 15, 16}$, 66 $\frac{B}{2, 3, 4}$ and surveyor Jagan Nath 1,335 square miles in sheets 57 $\frac{M}{12, 16}$, 57 $\frac{N}{7, 9, 13}$, 66 $\frac{A}{4}$, 66 $\frac{B}{1}$.

¼-inch traverse charts, prepared by the Madras Revenue Survey for sheets 57.M, 57.N, 66.A and 66.B, were completed on receipt, by entry of rays of all geodetic work falling in them, as well as the entry by plotting and rays of all topographical forest triangulation affecting them. When complete they were sent to the Photo-Zinco Section and direct blue prints on Bristol boards were supplied. The country triangulated had the principal and secondary series of the Madras Meridional and Coast Series, running through it, and on this the work was based. For the triangulation of the 4-inch reserved forests, charts from the ¼-inch charts already mentioned, on which the forests had been roughly indicated, were enlarged by photography on Bristol boards, every advantage being taken so that existing G. T. Bases, etc., on which the work was to be based, should appear on them. The work was undertaken late in the field, after the completion of the original 1-inch programme and was finished on the 20th June 1916.

The total outturn of triangulation was 10,041 square miles. 9,874 square miles, with a cost-rate of Rs. 3·2 per square mile, was for ordinary survey and 167 square miles, with a cost-rate of Rs. 29·8 per square mile, was for special forest survey on the 4-inch scale. The high cost-rate of the latter is due to the fact that the areas are scattered and that there was delay in obtaining sanction for the commencement of the special forest survey.

Traversing.— As there was no opportunity to start the theodolite traversing of the boundaries of the reserved forests for survey on the 4-inch scale, owing to the lateness of the season and want of men, it was held over, to be undertaken the first thing before the whole of the party left recess in 1916, when work in this line will be put in hand in order to have data ready for the special 4-inch survey for season 1916-17.

Recess Duties.—The fair drawing of the survey completed was distributed as follows:—

No. 1 Section.—Under Mr. Norman, sheets 57 $\frac{O}{4, 7, 8, 11, 12}$.

No. 2 Section.—Under Mr. West, sheets 57 $\frac{O}{15, 16}$, 66 $\frac{C}{3, 4, 7, 8}$.

No. 3 Section.—Under Mr. Butterfield and, while he was on leave, under the officer in charge assisted by Mr. Shaikh Muhammad Salik, sheets 57 $\frac{O}{1, 2, 3, 5, 6}$.

No. 4 Section.—Under Mr. Abdul Hakk, sheets 57 $\frac{P}{9, 10, 13, 14}$, 66 $\frac{D}{1, 2, 3, 4, 5}$.

There are 23 sheets (excluding sheets 66 $\frac{D}{4, 5}$ which are being drawn as outriggers to sheets 66 $\frac{D}{3, 1}$ respectively) for fair drawing, at the end of the year all of them were in hand and

Digitized by Google

fairly advanced, two have been completed and finally examined and two more are under final examination. The drawing is heavy and the typing severe, names in certain sheets average 25 letters, and the average number of names in a sheet is 400. For the advancement shown in fair drawing, the members of the party deserve every credit and have worked hard. No. 4 Drawing Office lent some draftsmen to assist the fair drawing.

The total outturn of fair drawing is 6002 square miles and the cost-rate is Rs. 3·9 per square mile.

Every endeavour is being made to complete the computations of the season's triangulation, and a satisfactory advance in this direction has been made, as all data for the 4-inch reserved forests in sheets 57 $\frac{N}{1, 2, 5, 6, 7, 8}$ and the data for the coming field programme in sheets 57 $\frac{N}{9, 10, 11, 12, 13, 14, 15, 16}$, 66 $\frac{B}{1, 2, 3, 4}$ have been completed as well as the setting up and partial completion of the main triangles in the remainder of the work. Work in the above line left undone will be put in hand and completed by the party computers during the field season. Madras Revenue Survey trijunctions fixed by party triangulation in the coming season's programme have been computed and compared with values supplied by the Madras Revenue Survey from reductions of their rectangular coordinates to spherical and disclose an average difference of about 47 feet in Latitude and 75 feet in Longitude.

During the year the party has received several triangulation charts from the Superintendent of the Trigonometrical Survey, in addition to those in hand from last year. A start has been made in this line to see as many through but the section is small and as computations are heavy and pressing, it has only been found possible to complete two *viz.* 48.L and 57.L. The above section has been under Mr. Simons who, in addition, has the general supervision of the computation section assisted by Mr. Harihara Iyer.

A small section has been set apart to help in abstracting, copying and re-checking of trigonometrical data of forest triangulation previously computed, and triangulation data of the past season completed and under completion both for the coming triangulation and detail survey. This section has also completed the projection and plotting, etc. of 1-inch field traverse charts, the tracing of 4-inch reserved forests' margins previously surveyed and adjoining the survey of forests to be surveyed on the same scale during the coming field season, and the plotting and general completion of blue print reproductions of sheets received from the Madras Revenue Survey, etc.

Miscellaneous.— With the exception of the fairly high hills where communications are few and villages far distant, the remainder of the country is well supplied with railways, roads and cart tracks, making access easy and quick. The Buckingham canal, linking up as it does the back waters of the Pulicat lake and Ennore, insures inland communications throughout a long stretch of country on the east coast.

The town of Madras and other fairly big towns and many places of historical interest fall in the area. The country is irrigated by innumerable artificial tanks and wells, and by many rivers, combining with natural fertility a deserving reward to the toil of the husbandman.

Work was considerably helped by the network of communications existing throughout the area and by the facility of procuring double bullock carts, which are plentiful and of good dimensions, on requisition. Jutkas or one horse country passenger cabs ply for hire on nearly all main roads and at all railway stations. Coolies are difficult to obtain during the paddy season at inland villages, owing to the great request they are in by the villagers, to sow and reap the harvests of which three are gathered in between November and April. Numerous field distributaries, from all sources of water, help to irrigate the ground. This ground when under cultivation hampers the work as chaining can only be resorted to and the chain men find a difficulty in progression. The surveyor also has to meander to his forward station doing a distance out of proportion to what he would do otherwise, were the country dry and passable.

The greatest difficulty was experienced in the survey of the district of Madras where the surveyor had to find his opportunity for work during the hustle and traffic of a big city, in the lulls that supervened or by starting work in the early morning hours, when the turmoil of the day had not begun. Many delays were experienced, owing to owners of property not giving permission, although a credential, introducing the surveyor to private estate owners, from the Collector was forthcoming. The above however occurred rarely and generally the credential more than satisfied its object *viz.* the progress of work. Another letter for permission to enter and survey Fort St. George was procured from the military authorities and was of great help.

Digitized by Google

No. 8 PARTY (MADRAS).

By W. F. E. Adams.

The majority of the party remained in Bangalore throughout the year and commenced a programme of fair drawing for ½-inch maps in addition to completing the arrears of fair drawing for 1-inch maps. Triangulation was carried out in sheets 58 $\frac{G}{11,12,15,16}$, 58 $\frac{H}{11,12,14,15,16}$, 58 $\frac{K}{3,4,7,8,11,12,15,16}$, 58 $\frac{L}{1,2,3}$, 58 $\frac{O}{3,7,8}$.

The country triangulated was very flat.

The field season opened on the 30th November 1915 and closed on the 1st June 1916. The head-quarters of the party remained at Bangalore throughout the year.

Personnel.

Provincial Officers.

Mr. W. F. E. Adams, in charge.
" M. Mahadeva Mudaliar, M. A.

Upper Subordinate Service.

Rai Sahib Anantarao Dhondiba Mandhre.
Mr. K. Narayanasvami Chetti.

Lower Subordinate Service.

27 Surveyors, etc.

The health of the party was good.

Topography.—No detail survey was undertaken by the party during the year under report.

Triangulation.—The country in sheets 58 $\frac{G}{11,12,15,16}$ was favourable for triangulation while that in degree sheets 58.K and 58.L was almost a dead flat with a slight slope of only a few feet per mile towards the sea. The country inland consists of black cotton soil, immediately succeeded by deep sand near the coast. Owing to the black cotton soil, the country is almost impassable in wet weather. It is covered with dense groves of trees especially round villages, and intersected by a net-work of bunds, dykes, supply channels and tanks. The fields are filled with crops growing to a height of nearly 10 feet and most of the tank beds are overgrown with a dense thicket of thorns of a kind of hard and matted *babul* which is exceedingly difficult to clear. The coast country is covered with palmyra trees and thorn jungle and in places with cocoanut groves.

Mr. Mahadeva Mudaliar triangulated 2,234 square miles in sheets 58 $\frac{G}{15,16}$, 58 $\frac{K}{3,4,7,8,11,12,15,16}$, 58 $\frac{O}{3,7,8}$. Mr. Narayanasvami Chetti, a beginner in this class of work, was instructed by Mr. Mahadeva Mudaliar at the commencement of the field season for about a month, after which he started on his own and completed 1,591 square miles in sheets 58 $\frac{G}{11,12,15,16}$, 58 $\frac{H}{11,12,14,15,16}$, 58 $\frac{L}{1,2,3}$.

The South-East Coast Series from Tuticorin to Rāmnād was a great help to the triangulator. In fact it was the Tower Stations of this series that made minor triangulation in degree sheet 58.K possible. Wooden scaffolding had to be built round these Tower Stations for observations, though it was with great difficulty that materials for it were procured from the neighbouring villages. It was again a laborious task to reclear the lines, now overgrown with trees, between stations which were mutually rendered visible in 1874-75. Many of the Great Trigonometrical Stations along the coast had disappeared owing to the sand-waves which travel from west-south-west to east-north-east, drifting the tops of sand ridges. In degree sheet 58.K triangulated this year, there were as many as 26 stations (minor) made on tops of houses, churches, temples and forts.

The total area triangulated was 3,825 square miles and the cost-rate per square mile is Rs. 4·4.

Recess Duties.—Mr. Anantarao Dhondiba Mandhre was in charge of the fair drawing section. During his absence on one month's privilege leave Mr. Narayanasvami Chetti supervised the section.

1-inch sheets 58 $\frac{D}{9,14,15}$, 58 $\frac{G}{7,8}$, 58 $\frac{H}{1,2,3}$, arrears from the previous year, were completed and submitted for publication. ½-inch sheets 49 $\frac{N}{N.E.}$, 58 $\frac{C}{S.W.}$ were completed and submitted for publication, 58 $\frac{B}{N.E.}$, 58 $\frac{C}{N.W.}$ are practically completed and 48 $\frac{K}{N.E., S.E.}$, 48 $\frac{L}{N.E., S.E.}$, 58 $\frac{B}{N.W., S.W., S.E.}$, 58 $\frac{C}{N.E., S.E.}$ are in hand.

The total area fair drawn for ½-inch maps was 5,052 square miles and cost-rate per square mile is Rs. 4·1.

Mr. Mahadeva Mudaliar was in charge of the computing section, and the computations of all the triangulation are expected to be completed by the end of November 1916.

Triangulation charts 58.C and 58.D will be completed on the new system by the end of December 1916.

Digitized by Google

EASTERN CIRCLE.

(*Vide* Index Maps 3 and 6).

Summary.—The Circle was under the superintendence of Lieutenant-Colonel R. T. Crichton, C. I. E., I. A. and comprised Nos. 9, 10, 11 and 12 Parties and No. 5 Drawing Office.

6931 square miles were surveyed during the year consisting of:—

300	square miles of	½-inch survey.
50	do.	½-inch reconnaissance survey.
5407	do.	1-inch survey.
65	do.	1-inch revision survey.
981	do.	2-inch survey.
128	do.	4-inch survey.

No detail survey was undertaken by No. 9 Party during the year under report. This party carried out a total of 682 linear miles of traversing over an area of 1504 square miles.

No. 9 PARTY (BENGAL).

By J. Smith.

PERSONNEL.

Provincial Officers.

Mr. J. Smith, in charge.
" Dhani Ram Verma.
" E. M. Kenny.
" Amar Krishna Mitra, up to 31st March 1916 and from 6th July 1916.

Upper Subordinate Service.

Mr. Dalbir Rai.
" Ram Singh.
" Amulya Charan Ghosh (Probationer).
" Gopal Lal Mitra (Probationer).

Lower Subordinate Service.

26 Surveyors, etc.

With the exception of the traversing in advance for one-inch detail survey of sheets 79 $\frac{A}{4, 8, 11, 12, 15 \& 16}$ no field programme was allotted to this party which was consequently employed on half-inch mapping throughout the year. In January four surveyors, and in April one Provincial Officer, were transferred temporarily to No. 11 Party till close of its field season.

Traversing.—The area traversed comprised portions of the Burdwān, Hooghly, Nadiā and Jessore districts.

The section consisting of three surveyors and two pupils under Mr. Ram Singh commenced field work on the 25th October 1915, and closed on the 28th March 1916.

The officer in charge of the party inspected the section on the 20th and 21st December 1915, and again at the end of March to supervise the closing of the field season. 682 linear miles of traverse were run, fixing 2707 intersected points such as trees, temples, etc., over an area of 1504 square miles, at a total cost of Rs. 11,610 which works out to Rs. 17 per linear mile. The health of the section was on the whole good. One of the pupils had a bad attack of malaria which incapacitated him for work for a month, but besides this, no other protracted cases of illness occurred. The country surveyed was absolutely flat, low-lying and cut up by numerous bīls and rivers.

Recess duties.—Computations of the traversing done have been completed, the mean error in the chaining working out to ·9 of a link per 1000 links, and in angular observation to 5 seconds per station.

Half-inch mapping.—15 sheets have been completed and despatched to the Circle office for submission for publication during the year, *viz.* 73 $\frac{B}{N.E.}$, $\frac{F}{N.E., N.W., S.E., S.W.}$; 78 $\frac{N}{N.E., S.E., N.W., S.W.}$, $\frac{O}{N.E., N.W., S.E.}$, $\frac{P}{N.W., S.W.}$ and $\frac{P}{S.E.}$. This leaves one sheet of programme of 1914-15 *viz.* 78 $\frac{P}{N.E.}$ still in hand which is completed but not yet fully examined.

Of the 9 sheets allotted in programme of 1915-16 *viz.* 72 $\frac{L}{S.W.}$; 73 $\frac{B}{N.W.}$; 78 $\frac{O}{S.W.}$; 83 $\frac{D}{N.W., N.E.}$, $\frac{F}{N.W., S.W.}$; 84 $\frac{K}{N.W., S.W.}$ all are nearing completion excepting 83 $\frac{F}{N.W.}$ of which material has not been received. In addition to these sheets 94 $\frac{F}{N.W., N.E., S.W.}$ have been put in hand.

Mr. Dhani Ram Verma supervised the mapping of sheets 72 $\frac{L}{S.W.}$; 73 $\frac{F}{N.E., S.E.}$; 78 $\frac{O}{N.E., S.W.}$, $\frac{P}{N.E., S.E., S.W.}$; 84 $\frac{K}{N.W.}$ and 94 $\frac{F}{S.W.}$.

Mr. E. M. Kenny supervised the mapping of sheets 73 $\frac{B}{N.E., N.W.}$; 78 $\frac{N}{N.W., S.W.}$, $\frac{O}{N.W.}$, $\frac{P}{S.W., S.E.}$; 83 $\frac{D}{N.W., N.E.}$, $\frac{F}{S.W.}$ and 84 $\frac{K}{S.W.}$.

Mr. Amar Krishna Mitra supervised the mapping of sheets 73 $\frac{F}{N.W., S.W.}$; 78 $\frac{N}{N.E., S.E.}$, $\frac{O}{S.E.}$ and $\frac{P}{N.W.}$

Digitized by Google

No. 8 PARTY (MADRAS).

By W. F. E. Adams.

The majority of the party remained in Bangalore throughout the year and commenced a programme of fair drawing for ½-inch maps in addition to completing the arrears of fair drawing for 1-inch maps. Triangulation was carried out in sheets 58 $\frac{G}{11, 12, 15, 16}$, 58 $\frac{H}{11, 12, 14, 15, 16}$, 58 $\frac{K}{3, 4, 7, 8, 11, 12, 15, 16}$, 58 $\frac{L}{1, 2, 3}$, 58 $\frac{O}{3, 7, 8}$.

The country triangulated was very flat.

The field season opened on the 30th November 1915 and closed on the 1st June 1916. The head-quarters of the party remained at Bangalore throughout the year.

Personnel.

Provincial Officers.

Mr. W. F. E. Adams, in charge.
" M. Mahadeva Mudaliar, M. A.

Upper Subordinate Service.

Rai Sahib Anantarao Dhondiba Mandhre.
Mr. K. Narayanasvami Chetti.

Lower Subordinate Service.

27 Surveyors, etc.

The health of the party was good.

Topography.—No detail survey was undertaken by the party during the year under report.

Triangulation.—The country in sheets 58 $\frac{G}{11, 12, 15, 16}$ was favourable for triangulation while that in degree sheets 58.K and 58.L was almost a dead flat with a slight slope of only a few feet per mile towards the sea. The country inland consists of black cotton soil, immediately succeeded by deep sand near the coast. Owing to the black cotton soil, the country is almost impassable in wet weather. It is covered with dense groves of trees especially round villages, and intersected by a net-work of bunds, dykes, supply channels and tanks. The fields are filled with crops growing to a height of nearly 10 feet and most of the tank beds are overgrown with a dense thicket of thorns of a kind of hard and matted *babul* which is exceedingly difficult to clear. The coast country is covered with palmyra trees and thorn jungle and in places with cocoanut groves.

Mr. Mahadeva Mudaliar triangulated 2,234 square miles in sheets 58 $\frac{G}{15, 16}$, 58 $\frac{K}{3, 4, 7, 8, 11, 12, 15, 16}$, 58 $\frac{O}{3, 7, 8}$. Mr. Narayanasvami Chetti, a beginner in this class of work, was instructed by Mr. Mahadeva Mudaliar at the commencement of the field season for about a month, after which he started on his own and completed 1,591 square miles in sheets 58 $\frac{G}{11, 12, 15, 16}$, 58 $\frac{H}{11, 12, 14, 15, 16}$, 58 $\frac{L}{1, 2, 3}$.

The South-East Coast Series from Tuticorin to Rāmnād was a great help to the triangulator. In fact it was the Tower Stations of this series that made minor triangulation in degree sheet 58.K possible. Wooden scaffolding had to be built round these Tower Stations for observations, though it was with great difficulty that materials for it were procured from the neighbouring villages. It was again a laborious task to reclear the lines, now overgrown with trees, between stations which were mutually rendered visible in 1874-75. Many of the Great Trigonometrical Stations along the coast had disappeared owing to the sand-waves which travel from west-south-west to east-north-east, drifting the tops of sand ridges. In degree sheet 58.K triangulated this year, there were as many as 26 stations (minor) made on tops of houses, churches, temples and forts.

The total area triangulated was 3,825 square miles and the cost-rate per square mile is Rs. 4·4.

Recess Duties.—Mr. Anantarao Dhondiba Mandhre was in charge of the fair drawing section. During his absence on one month's privilege leave Mr. Narayanasvami Chetti supervised the section.

1-inch sheets 58 $\frac{D}{9, 14, 15}$, 58 $\frac{G}{7, 8}$, 58 $\frac{H}{1, 2, 3}$, arrears from the previous year, were completed and submitted for publication. ½-inch sheets 49 $\frac{N}{N.E.}$, 58 $\frac{C}{S.W.}$ were completed and submitted for publication, 58 $\frac{B}{N.E.}$, 58 $\frac{C}{N.W.}$ are practically completed and 48 $\frac{K}{N.E., S.E.}$, 48 $\frac{L}{N.E., S.E.}$, 58 $\frac{B}{N.W., S.W., S.E.}$, 58 $\frac{C}{N.E., S.E.}$ are in hand.

The total area fair drawn for ½-inch maps was 5,052 square miles and cost-rate per square mile is Rs. 4·1.

Mr. Mahadeva Mudaliar was in charge of the computing section, and the computations of all the triangulation are expected to be completed by the end of November 1916.

Triangulation charts 58.C and 58.D will be completed on the new system by the end of December 1916.

Digitized by Google

EASTERN CIRCLE.

(*Vide* Index Maps 3 and 6).

Summary.—The Circle was under the superintendence of Lieutenant-Colonel R. T. Crichton, C. I. E., I. A. and comprised Nos. 9, 10, 11 and 12 Parties and No. 5 Drawing Office.

6931 square miles were surveyed during the year consisting of:—

300	square miles of	½-inch survey.
50	do.	¼-inch reconnaissance survey.
5407	do.	1-inch survey.
65	do.	1-inch revision survey.
981	do.	2-inch survey.
128	do.	4-inch survey.

No detail survey was undertaken by No. 9 Party during the year under report. This party carried out a total of 682 linear miles of traversing over an area of 1504 square miles.

No. 9 PARTY (BENGAL).

By J. Smith.

PERSONNEL.

Provincial Officers.

Mr. J. Smith, in charge.
" Dhani Ram Verma.
" E. M. Kenny.
" Amar Krishna Mitra, up to 31st March 1916 and from 6th July 1916.

Upper Subordinate Service.

Mr. Dalbir Rai.
" Ram Singh.
" Amulya Charan Ghosh (Probationer).
" Gopal Lal Mitra (Probationer).

Lower Subordinate Service.

26 Surveyors, etc.

With the exception of the traversing in advance for one-inch detail survey of sheets 79 $\frac{A}{4, 8, 11, 12, 15 \& 16}$ no field programme was allotted to this party which was consequently employed on half-inch mapping throughout the year. In January four surveyors, and in April one Provincial Officer, were transferred temporarily to No. 11 Party till close of its field season.

Traversing.—The area traversed comprised portions of the Burdwān, Hooghly, Nadiā and Jessore districts.

The section consisting of three surveyors and two pupils under Mr. Ram Singh commenced field work on the 25th October 1915, and closed on the 28th March 1916.

The officer in charge of the party inspected the section on the 20th and 21st December 1915, and again at the end of March to supervise the closing of the field season. 682 linear miles of traverse were run, fixing 2707 intersected points such as trees, temples, etc., over an area of 1504 square miles, at a total cost of Rs. 11,610 which works out to Rs. 17 per linear mile. The health of the section was on the whole good. One of the pupils had a bad attack of malaria which incapacitated him for work for a month, but besides this, no other protracted cases of illness occurred. The country surveyed was absolutely flat, low-lying and cut up by numerous bīls and rivers.

Recess duties.—Computations of the traversing done have been completed, the mean error in the chaining working out to ·9 of a link per 1000 links, and in angular observation to 5 seconds per station.

Half-inch mapping.—15 sheets have been completed and despatched to the Circle office for submission for publication during the year, *viz.* 73 $\frac{B}{N.E.}$, $\frac{F}{N.E., N.W., S.E., S.W.}$; 78 $\frac{N}{N.E., S.E., N.W., S.W.}$, $\frac{O}{N.E., N.W., S.E.}$, $\frac{P}{N.W., S.W.}$ and $\frac{P}{S.E.}$. This leaves one sheet of programme of 1914-15 *viz.* 78 $\frac{P}{N.E.}$ still in hand which is completed but not yet fully examined.

Of the 9 sheets allotted in programme of 1915-16 *viz.* 72 $\frac{L}{S.W.}$; 73 $\frac{B}{N.W.}$; 78 $\frac{O}{S.W.}$; 83 $\frac{D}{N.W., N.E.}$, $\frac{F}{N.W., S.W.}$; 84 $\frac{K}{N.W., S.W.}$ all are nearing completion excepting 83 $\frac{F}{N.W.}$ of which material has not been received. In addition to these sheets 94 $\frac{F}{N.W., N.E., S.W.}$ have been put in hand.

Mr. Dhani Ram Verma supervised the mapping of sheets 72 $\frac{L}{S.W.}$; 73 $\frac{F}{N.E., S.E.}$; 78 $\frac{O}{N.E., S.W.}$, $\frac{P}{N.E., S.E., S.W.}$; 84 $\frac{K}{N.W.}$ and 94 $\frac{F}{S.W.}$.

Mr. E. M. Kenny supervised the mapping of sheets 73 $\frac{B}{N.E., N.W.}$; 78 $\frac{N}{N.W., S.W.}$, $\frac{O}{N.W.}$, $\frac{P}{S.W., S.E.}$; 83 $\frac{D}{N.W., N.E.}$, $\frac{F}{S.W.}$ and 84 $\frac{K}{S.W.}$.

Mr. Amar Krishna Mitra supervised the mapping of sheets 73 $\frac{F}{N.W., S.W.}$; 78 $\frac{N}{N.E., S.E.}$, $\frac{O}{S.E.}$ and $\frac{P}{N.W.}$

Digitized by Google

The cost-rate of the half-inch mapping in the report of last year was based on 10 completed sheets, but for this year only four completed sheets have been taken into calculation; consequently it is nearly double of what it was last year.

No. 10 PARTY (UPPER BURMA).

By Major E. T. Rich, R. E.

1. The recess office of the party closed in Maymyo on October 23rd 1915 and opened in Myitkyinā on October 26th 1915.

The office at Myitkyinā was closed on May 25th 1916 and the recess office was opened in Maymyo on May 29th 1916 where it remained for the rest of the year.

The health of the party was not good during the winter season, as there were numerous cases of malaria from which two khalasis died.

2. *Topography.*—Surveys were completed over an area of 2857 square miles in Upper and Lower Burma at a cost of Rs. 1,15,324.

This area was surveyed as follows:—

2220 sq. miles of new		1-inch survey.
222	do.	2-inch do.
300	do.	½-inch do.
65	do.	1-inch revision survey.
50	do.	½-inch reconnaissance in unadministered territory.
Total 2857 square miles.		

Personnel.

Imperial Officer.

Major E. T. Rich, R. E., in charge.

Provincial Officers.

Mr. W. G. Jarbo.
" H. B. Simons till 29th June 1916.
" A. V. Dickson from 22nd May 1916.
" A. F. Murphy.
" D. N. Banerjee, L. C. E.

Upper Subordinate Service.

Khan Sahib Hayat Muhammad.
Mr. Maung Kyaw Nyein.
" D. N. Saha.
Rai Sahib Ram Prasad.

Lower Subordinate Service.

27 Surveyors, etc.

The country surveyed in Upper Burma consisted of thickly wooded hills rising over 4000 feet above sea level and cut up by numerous low lying valleys.

In Lower Burma the country surveyed lay between the sea coast and the main range forming the western watershed of the Tenasserim river, together with a number of islands lying off the coast.

It varied from the steep densely wood hills along the Tenasserim watershed which were over 6000 feet high, practically uninhabited and with no communications, to the flat alluvial land covered with villages nearer the sea whilst the sea coast was everywhere fringed with mangrove swamps.

The party was divided into three survey camps under Major E. T. Rich, Messrs. W. G. Jarbo and H. B. Simons respectively.

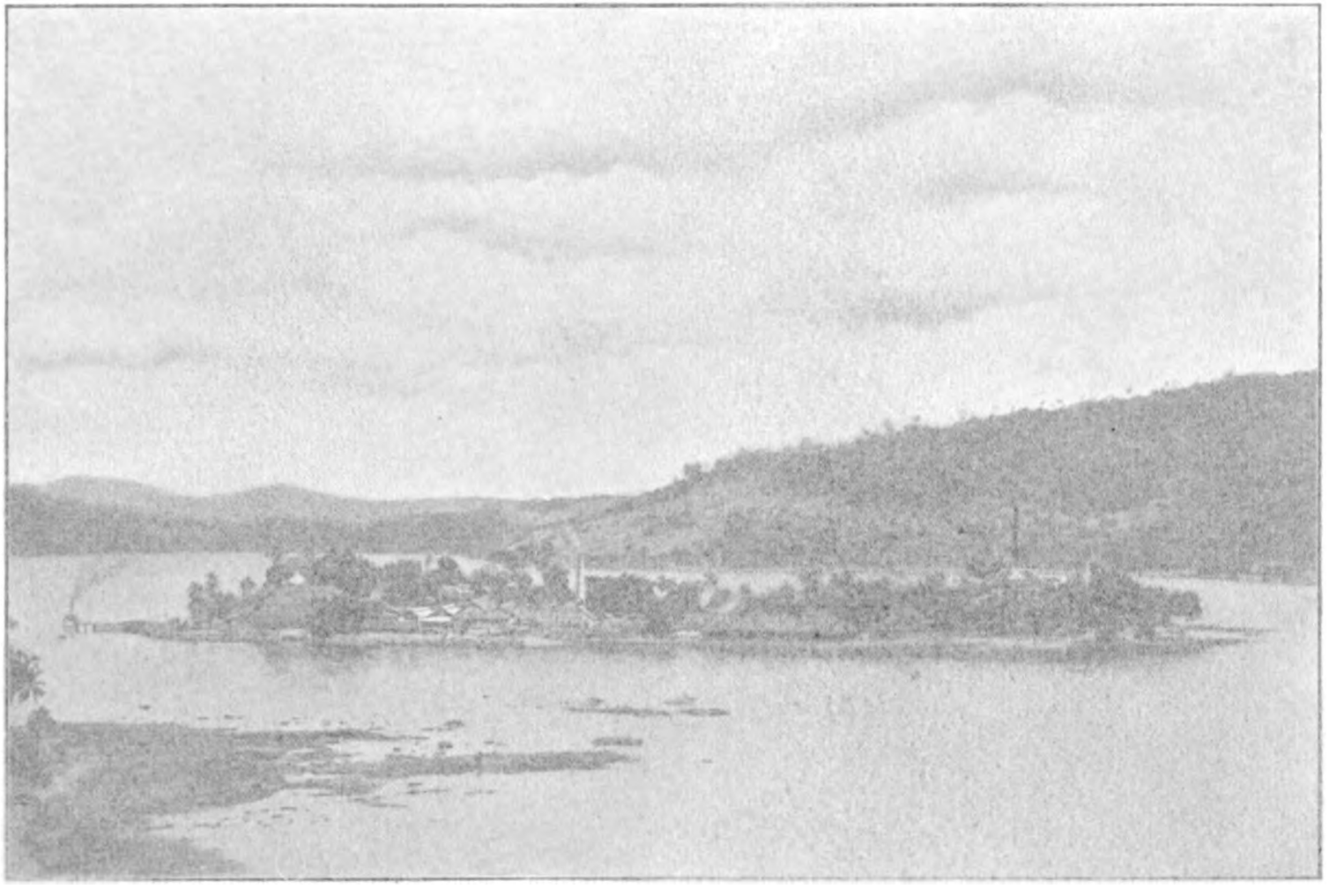
Camp No. 1.—In charge of Major E. T. Rich, with one Upper Subordinate, Khan Sahib Hayat Muhammad and 2 surveyors completed an area of 311 square miles on the 1-inch scale in parts of sheets 92 $\frac{C}{16}$, $\frac{G}{5, 10}$ and 300 square miles on the ½-inch scale with 50 square miles of reconnaissance on the same scale in parts of sheets 92 $\frac{F}{11, 12, 15, 16}$.

Camp No. 2.—In charge of Mr. W. G. Jarbo assisted by one Provincial Officer, Mr. A. F. Murphy and one Upper Subordinate, Mr. Maung Kyaw Nyein in sub-charge of sections with one Provincial Officer Mr. D. N. Banerjee and 15 surveyors plane-tabling completed an area of 757 square miles on the 1-inch scale, 222 square miles on the 2-inch scale and 65 square miles of 1-inch revision survey, in the Kathā, Upper Chindwin and Myitkyinā districts in sheets 92 $\frac{C}{3, 4, 8}$ and parts of sheets 92 $\frac{D}{5}$ and 83 $\frac{O}{16}$.

Camp No. 3.—In charge of Mr. H. B. Simons with one Upper Subordinate, Mr. D. N. Saha and 7 surveyors, completed an area of 1152 square miles on the 1-inch scale in the Tavoy and Mergui districts in sheets 95 $\frac{K}{4, 7, 8, 11, 12}$, $\frac{L}{1, 5, 9}$ and parts of 95 $\frac{K}{15, 16}$, $\frac{L}{13}$.

This camp was practically an independent charge as it was situated over 1000 miles from the party head-quarters in Myitkyinā and Mr. Simons is to be commended for the good arrangements he made for transport and supplies.

Digitized by Google



Digitized by Google

Digitized by Google

The average cost-rates and outturns were as follows:—

Half-inch survey—

Cost-rate	Rs. 8·6	per square mile.
Outturn	58·6	square miles per month.

One-inch survey—

Cost-rate	Rs. 41·8	per square mile.
Outturn	19·9	square miles per month.

One-inch revision survey—

Cost-rate	Rs. 7·7	per square mile.
Outturn	32·9	square miles per month.

Two-inch survey—

Cost-rate	Rs. 90·5	per square mile.
Outturn	5·8	square miles per month.

3. *Triangulation.*—New triangulation was completed over an area of 2000 square miles at a cost of Rs. 12,358 including the computations.

(*a*) Rai Sahib Ram Prasad triangulated an area of 1850 square miles in sheets $92\ \frac{F}{5, 6, 9, 10, 13, 14}$ of the Putao district.

(*b*) Khan Sahib Hayat Muhammad triangulated an area of 150 square miles near Myitkyinā whilst re-observing at four stations in order to refix the stone at a station which had been removed by some military signallers.

Great credit is due to the arrangements made by Mr. Ram Prasad who was working most of the winter in high snowy hills under great difficulties over 15 days march from his base in Myitkyinā. He made all his arrangements for transport and rationing his men himself and was away for 7 months without being visited by any officer of the party.

The country triangulated by both triangulators consisted of high thickly wooded hills and deep valleys sparsely inhabited.

The average cost-rate including computing is Rs. 6·2 per square mile.

4. *Recess duties.*—(*a*) The fair drawing was divided into two sections.

No. 1 Section.—In charge of Mr. W. G. Jarbo assisted by Mr. A. V. Dickson completed and sent for publication the 6 frontier sheets left unfinished last year, besides drawing sheets $92\ \frac{C}{3, 4, 8, 16}$ and $92\ \frac{D}{5}$. None of these five sheets will be ready for publication before the party takes the field, owing to the time spent in completing the 6 frontier sheets.

No. 2 Section.—In charge of Mr. A. F. Murphy assisted by Messrs. D. N. Banerjee and D. N. Saha drew sheets $92\ \frac{K}{4 \text{ and } 8, 7, 11, 12}, \frac{L}{1 \text{ and } 5, 9}$ all of which will be sent for publication before the party takes the field.

The cost-rate of fair drawing comes to Rs. 8·5 per square mile.

(*b*) All the computations of the triangulation done during the field season were completed during the recess in charge of Khan Sahib Hayat Muhammad assisted by Rai Sahib Ram Prasad with one computer.

The triangulation charts were also brought up to date.

(*c*) Mr. Maung Kyaw Nyein was employed instructing 9 newly enlisted pupils of Nos. 10 and 11 Parties in field work and fair drawing.

5. *Outturn and Cost-rates.*—The cost-rates shew an increase all round except for triangulation and one-inch revision survey which shew a decrease.

This increase of cost-rates is however rather misleading, as, taken as a whole, the total cost of the party for the year shows an increase of only Rs. 17,339 or 12½ per cent. in excess of last year's cost, against an additional area of 739 square miles of survey equal to 25 per cent. in excess of last year's outturn, so that the cost-rates on the whole may be considered satisfactory.

The cost-rate for 1-inch survey is increased by Rs. 8·2 per square mile, being Rs. 41·8 compared with Rs. 33·56 last year, Rs. 22·38 in 1913-14 and 23·21 in 1912-13.

For 2-inch survey the cost-rate is increased by Rs. 6·9 per square mile, being Rs. 90·5 compared with Rs. 83·60 last year, Rs. 54·51 in 1913-14 and Rs. 57·84 in 1912-13.

For triangulation, the cost-rate is very satisfactory being reduced by Re. 0·9 per square mile. It is Rs. 6·2 compared with Rs. 7·07 last year, Rs. 8·41 in 1913-14 and Rs. 13·52 in 1912-13.

Digitized by Google

For 1-inch revision survey the cost-rate is reduced by Re. 0·5 being Rs. 7·7 compared with Rs. 8·17 last year.

For mapping the cost-rate is increased by Rs. 1·6 per square mile, being Rs. 8·5 compared with Rs. 6·94 last year, Rs. 7·51 in 1913-14 and Rs. 10·91 in 1912-13.

This increase in cost is due to the time taken over the arrears of heavy hill sheets along the Burma-China border.

No. 11 PARTY (LOWER BURMA).

By J. O. Greiff.

Personnel.

Provincial Officers.

Mr. J. O. Greiff, in charge.
" O. J. H. Hart.
" C. O. Picard.
" A. J. Moore, from 11th October 1915 to 18th March 1916.

Upper Subordinate Service.

Rai Bahadur Lachman Daji Jadu.
Mr. P. C. Sen Gupta, B. Sc. (Probationer).

Lower Subordinate Service.

28 Surveyors, etc.

The original programme of the party consisted in the execution of the survey, on the 2-inch scale, of 398 square miles of reserved forest areas, in sheets 93 $\frac{R}{8, 12}$, 93 $\frac{C}{5, 9, 10, 13, 14}$, a special survey on the 4-inch scale, of 126 square miles of reserved forests in sheets 93 $\frac{B}{12}$, 93 $\frac{C}{5, 9}$ in the districts of Mandalay and Kyaukse, Upper Burma, and in the continuation of the ½-inch and ¼-inch mapping in recess quarters, during the field season, by the Maymyo Drawing Office.

For field operations two camps were originally formed, comprising two officers and seventeen surveyors.

The field camps left Maymyo on the 1st November and started work by the 10th November.

Towards the end of December, an urgent request was received from the Burma Government, for the survey, on the 1-inch scale of sheets 95 $\frac{F}{13}$, 95 $\frac{J}{6}$, 95 $\frac{L}{10, 11, 14, 15, 16}$, and 95 $\frac{P}{3, 4}$ maps of which were urgently needed, in connection with the Wolfram Mining Industry, in the districts of Tavoy and Mergui. Owing to the very important nature of the request the party was directed to immediately arrange to undertake the survey of these sheets. The Superintendent of the Circle personally discussed and arranged, with the executive officer, the principal details.

The new programme of work necessitated curtailing forest surveys round Maymyo, and re-distributing the personnel of the party. It was decided to survey only the forest areas required to complete 1-inch sheets 93 $\frac{B}{8, 12}$, 93 $\frac{C}{5, 9}$ to margins, and to utilise the surveyors so set free, with three from the drawing office, and eight others transferred from Nos. 9 and 12 Parties, to form two field camps, under Messrs. Picard and Lachman Daji Jadu, for work in Mergui and Tavoy.

The two additional camps arrived in Tavoy and Mergui, by the beginning of February. After making necessary arrangements for supplies, interpreters, boats etc., each surveyor was sent out to his particular bit of work. Owing to the lack of communications and long distances to be travelled in country boats, work was not actually started till about the 15th February.

The country surveyed in Upper Burma varied in elevation from 250 feet to over 4500 feet in the hills and was densely wooded with a heavy undergrowth of grass jungle. The river Nam Tu which is the boundary between the Baw and Yeyaman reserved forests, situated respectively in the districts of Mandalay and Kyaukse presented a formidable barrier to through communication, and to the survey of the hills along its flanks. The river in this part of its course is more of the nature of a mountain torrent, confined between high hills, which rise almost sheer and precipitous from the river bed. To survey these details frequent crossings of the river were necessary, a tedious operation on small bamboo rafts.

In Tavoy the hilly seaboard area in the extreme north-west of the district, north of the Heinze bay, and the upper reaches of the Tavoy river (Kaleinaung Chaung) were surveyed. In sheet 95 $\frac{J}{6}$, the main watershed, which is the administrative boundary between Burma and Siam, was found to be very much out in the old reconnaissance maps.

In Mergui the lower portions of the watershed between the seaboard and the Tenasserim valley, and part of the valley itself were surveyed. The country throughout was hilly, rising to an elevation of 2500 feet, clothed with huge trees, below which was a tangled undergrowth of bamboo, cane and other creepers. For plane-table fixings almost every hill

Digitized by Google

top had to be cleared. The ground in these dense forests is covered with heavy decayed vegetation, which makes the air within noisome. The country along the sea littoral is cut up by numerous tidal creeks fringed with dense mangrove swamps.

Owing to the existence of numerous waterways the district is practically devoid of roads and paths. For marches into the interior paths had to be cut and cleared. Except along the banks of the Tenasserim river the country is very sparsely populated, and east of the river is uninhabited for miles.

The country has a heavy rain fall, due to its proximity to the sea. From about the end of April rain was almost continuous. Constant rain, dense forest, swamp vegetation, leeches and other insect pests, precarious means of communication and supplies, rendered progress slow and difficult. All main detail was surveyed by means of plane-table traverses.

The Wolfram Mining Industry is for the present confined chiefly to the hilly area north of the village of Tenasserim. These are the foot hills of the range, that trends south through Tavoy and Mergui, and in this locality breaks up into a jumble of low hills, circled by the Tenasserim river, which due south assumes a westerly course, and then doubles back upon itself.

All supplies had to be arranged for from Mergui. Two depots were established from which the detached camps were supplied.

The question of transport was a matter of great difficulty. Mules were imported from as far away as Myitkyinā. The cost of their freight was a very heavy item of expenditure.

Through the Burma Government a motor launch was placed at the disposal of the party. The launch before being despatched from Rangoon was not overhauled, the consequence being that she was practically *hors de combat* from the day she was landed at Mergui.

The Tenasserim is a dangerous river to navigate owing to its being full of 'snags'. In the annual report for season 1891-92 it is stated, that the river is navigable by steam launch as far as Tenasserim only, thence country boats up as far as Tarabwin, after which only canoes can proceed. If this is correct, it is perhaps interesting to note the great change that has taken place in the deep channel of the river, for motor launches of over two feet draft, now go up as far as Tagu, three miles below Tarabwin, thence country boats as far as Pawut, thirty miles up, after which canoes or dugouts are used, owing to numerous rapids further ahead.

The field season opened on the 1st November 1915, and closed in Mergui on the 24th June 1916. Seven surveyors were kept out till about the middle of July, to complete sheets 95 $\frac{L}{14}$ and 95 $\frac{P}{3}$. The head-quarters of the party remained at Maymyo.

The old 1-inch maps prepared from surveys done between 1889-1893 were found to be very incorrect.

Topography.—The party was divided into three survey camps as follows :—

No. 1 Camp.— Mr. A. J. Moore in charge, and eleven surveyors, completed the survey of 285 and 128 square miles of reserved forest areas, on the 2-inch and 4-inch scales respectively, in sheets 93 $\frac{B}{8, 12}$, 93 $\frac{C}{5, 9, 10, 13, 14}$.

Mr. Moore received a commission in the Indian Army Reserve of Officers from the 19th March, when the section was taken over by Mr. A. K. Mitra, transferred temporarily from No. 9 Party.

No. 2 Camp.—Mr. C. O. Picard in charge, with Mr. Sen Gupta and 12 surveyors, completed the survey on the 1-inch scale of 1026 square miles in sheets 95 $\frac{L}{10, 14, 15, 16}$, 95 $\frac{P}{2, 3, 4}$. To the latter part of the season six additional surveyors were transferred to the section, to help to complete the survey of the mining areas and sheets 95 $\frac{L}{14}$, and 95 $\frac{}{3}$.

No. 3 Camp.—Rai Bahadur Lachman Daji Jadu in charge, and six surveyors, completed the survey of 286 square miles, on the 1-inch scale, in sheets 95 $\frac{F}{13}$ and 95 $\frac{J}{6}$.

In addition 70 square miles in sheets 93 $\frac{B}{6, 7, 10, 11}$ were surveyed, on the 1-inch scale, for the General Staff, Burma Division, for the preparation of the Artillery Practice Camp Map. The enlarged map, scale 3 inches = 1 mile, was produced direct from the field original, and was very satisfactory.

The cost-rate per square mile for each class of work is as follows :—

1-inch detail survey Rs. 50·7, 2-inch Rs. 78·4, 4-inch Rs. 142·9. The rates are high owing to the heavy cost of transport, and high rates for local labour.

Digitized by Google

Triangulation.—Sheets 95 $\frac{L}{16}$ and 95 $\frac{P}{4}$, in the Mergui district were triangulated by surveyor Muhammad Yusuf Khan. The triangulation was an extension south from that done in season 1913-14. The country was similar to that topographically surveyed. The area was 580 square miles, and the cost-rate Rs. 4·5 per square mile.

Recess duties.—The fair drawing for the season was divided between the Maymyo Drawing Office, and a section under Mr. Lachman Daji Jadu.

Maymyo Drawing Office.—Was under the charge of Mr. Hart throughout the year, and the outturn of fair drawing done is very creditable. Seven ½-inch sheets 84 $\frac{M}{N.E., S.W., S.E.}$; 92 $\frac{G}{S.W.}$, $\frac{L}{S.W., S.E.}$; 93 $\frac{I}{N.E.}$ amounting to 7, 614 square miles, and 3,780 square miles in degree sheets 84.N, 93.E, 93.I, were completed. The cost-rates for these are respectively Rs. 1·4 and Rs. 1·1 per square mile. Only the final examination of these sheets remains to be completed. It is hoped to be able to send these sheets for publication, during the next field season.

The drawing office has also taken up the fair drawing of 1-inch sheets 93 $\frac{B}{8, 12}$, 93 $\frac{C}{5, 9}$, 95 $\frac{L}{14}$, 95 $\frac{P}{3}$, of which 620 square miles have been completed.

The mapping section under Mr. Lachman Daji Jadu completed the fair drawing of 195 square miles, in sheets 95 $\frac{F}{13}$, 95 $\frac{J}{6}$, 95 $\frac{L}{10}$.

Owing to the prolonged field season, it has not been possible to complete the fair drawing of the 1-inch sheets during the recess season. The arrears of fair drawing will be completed by the drawing office, and the sheets sent for publication during the next field season.

During the recess season, four 1-inch plans of the Wolfram mining areas in Mergui, were prepared for the local authorities. The 1-inch plans were enlarged by photography to the scale 4 inches = 1 mile, and blue prints on the enlarged scale supplied to the Deputy Commissioner. These are to be utilised as the basis of a rigorous 4-inch survey, done on the ground, of each concessionnaire's property, and will be the legally recognised plan of each concession.

The cost-rate per square mile for fair drawing is Rs. 8·6.

Twenty-nine forest boundary plots, on the scale of 4-inch equal to 1 mile, were prepared during recess for the Forest Department.

No. 12 PARTY (ASSAM).

By Lieutenant-Colonel A. Mears, I.A.

Personnel.

Imperial Officer.

Lieut.-Colonel A. Mears, I.A.

Provincial Officers.

Rai Sahib Pramadaranjan Ray.
Mr. B.C. Newland.
" P. C. Mitra, B.A.
" H. H. Creed.

Upper Subordinate Service.

Mr. G. S. Bagchi (Probationer).

Lower Subordinate Service.

42 Surveyors, etc.

The previous season's operations were continued eastward along both banks of the Brahmaputra river and comprised sheets 83 $\frac{F}{13, 16}$, 83 $\frac{G}{13}$ and 83 $\frac{J}{1, 2, 3, 5, 6, 9}$. The programme was mainly carried out on the 1-inch scale but included the Nāmbar, Diphu, Rengmā, Dayāng, Kākadanga, Disai Valley, Disai and Holongāpār reserved forests totalling an area of 472 square miles surveyed on the 2-inch scale.

With the exception of about 250 square miles in sheets 83 $\frac{J}{3, 6}$, where an elevation of some 4000 feet is attained, the whole of the country under survey is practically flat. From the foot of the Nāgā Hills, except where these adjoin reserved forests, to the south bank of the Brahmaputra river the country is almost entirely under rice and tea cultivation, the area being one of the most important tea growing centres in the valley of the Brahmaputra.

The field season started about the middle of November and closed at the commencement of May by which date the weather had become very unsettled for plane-tabling; the traverse section remained in the field till nearly the end of that month. The health of the party was remarkably good considering the unhealthy nature of the Nāmbar and other reserved forests under survey, this may be chiefly ascribed to the regular issue of quinine and to the khalasis being supplied with thick linen socks as a protection from leech bites which otherwise are liable to turn into bad ulcers. One surveyor was invalided during the field season and five khalasis died.

Topography.—The party was divided into 4 camps for the execution of the detail survey programme.

Digitized by Google

Camp No. 1.—Under Rai Sahib Pramadaranjan Ray, with one Sub-Assistant Superintendent and 9 surveyors completed the survey of one sheet on the 2-inch scale after which he supervised the training section which surveyed 1 sheet on the 1-inch scale.

Camp No. 2.—Under Mr. Newland with a strength of 8 to 10 surveyors surveyed 3½ sheets on the 1-inch scale.

Camp No. 3.—Under Mr. P. C. Mitra with 9 to 12 surveyors completed two sheets on the 1-inch and 2-inch scales.

Camp No. 4.—Under Mr. H. H. Creed with the assistance of 2 surveyors surveyed 1 sheet.

Of the country under survey close on 750 square miles was covered with the densest of jungle which owing to the scarcity of villages and local labour necessitated surveyors' squads being increased to 12 khalasis; even with this number of men the progress was slow on account of the large areas of cane brake and evergreen jungle met with. Some difficulty was experienced in rationing surveyors and their squads in parts of the area which would have been considerably increased had not the Assam-Bengal railway traversed a portion of the Nāmbar forest. Except for the railway and one or two roads and paths, surveyors had to make their own communications and elephant transport was confined to the few existing paths owing to the heavy clearing needed when these were abandoned.

The plains adjoining the Brahmaputra river call for no particular mention resembling in most respects the country described in previous reports. An area of some interest is the Mājuli island situated between the Brahmaputra and Luhit rivers containing some of the most noted *Sattras* or religious colleges of Assam.

The sites of the ancient Kachāri cities Dimāpur and Kāsomāri fall in the area of operations as also that of Rangpur, the capital of the Ahom kings, the ruins of which lie about 2 miles south of Sibsāgar. The remains of the Kachāri cities are almost entirely buried in the dense jungle of the Diphu and Dayāng reserves; those of Rangpur are in better preservation and comprise many fine tanks and the ruins of temples and palaces. Descriptions of these interesting remains are to be found in the reports of the Archæological Survey.

The cost-rate for 1-inch survey for the season is practically identical with that of the previous year and may be considered favourable. The slight increase in the cost of the 2-inch survey is attributable to smaller individual outturns owing to the extremely dense nature of the forest growth and the necessity for the employment of larger squads of Hazāribāgh khalasis due to local labour being unobtainable.

Triangulation.—No triangulation was carried out by the party during the season under report.

Traversing.—Advance traversing was extended north and eastward into sheets 83 $\frac{I}{8, 11, 12, 14, 15, 16}$, $\frac{J}{13}$, $\frac{M}{2, 3, 4}$, $\frac{N}{1}$ over an area of some 1850 square miles for detail survey on the 1-inch scale. Selected stations such as bench-marks, bridges, mile and revenue stones to the number of 394 were permanently marked, in addition 809 zinc cylinders were embedded.

The country traversed was flat and of a similar nature to that under detail survey. The traverse survey cost-rate is slightly less than that for the previous year, this is mainly due to there having been no Provincial Officer in charge of the work; the rate may be taken as a favourable one for the nature of the country under traverse.

Recess duties.—The fair drawing of the season's outturn, comprising 8 one-inch sheets, has been carried out by 3 drawing sections under the supervision of Messrs. P. Ray (3 sheets), B. C. Newland (3 sheets) and P. C. Mitra (2 sheets). It was found possible to adopt direct mapping for 3½ sheets there being little or no distortion in the field sections, this has considerably expedited the progress of the work. Sheets 83 $\frac{F}{13, 16}$ and 83 $\frac{J}{1, 3}$ were submitted for publication before the close of the survey year and the remaining sheets 83 $\frac{J}{2, 5, 6, 9}$ will be completed before the party takes the field.

In addition to the above, sheets 83 $\frac{F}{5, 6, 10, 12, 14, 15}$ of the previous season have been submitted for publication during the year under report making a total of 10 one-inch sheets. The field sections of the reserved forest area surveyed on the 2-inch scale in sheet 83 $\frac{G}{13}$ have been sent to the Forest Map Office for fair mapping, the survey being a purely forest one.

The cost-rate for fair mapping works out at a somewhat higher average per square mile than in previous years due to the large amount of 2-inch survey having curtailed the area for fair mapping.

Rough triangulation charts for sheets 83. F and 83. J with manuscript lists of data have been prepared and submitted to the Superintendent of the Trigonometrical Survey. The computations of the traversing, carried out during the field season, have been completed, the work has proved of good quality.

Digitized by Google

TABLE I.

OUT-TURNS OF DETAIL SURVEY.

Scale.	Class of Survey	Circle.	Party.	Locality.	Out-turn, square miles.		Average number of fixings per square mile.	
					Total.	Average per man per month of 24 working days.	*In situ* (by resection).	Plane-table traverse.
¼-inch .	Revision Survey .	N	No. 1	Kashmīr and Jammu	51	20·4	1·2	
½-inch .	Survey .	S	No. 6	Hyderābād ...	9,886	83·5	4·6	
		E	No. 10	Upper Burma ...	300	58·6	1·0	
1-inch .	Survey .	N	No. 1	Kashmīr and Jammu	588	48·7	2·0	
		N	No. 2	Punjab & Rājputāna	1,602	47·0	6·0	5·0
		N	No. 4	United Provinces and Nepāl ...	130	19·4	8·3	12·8
		S	No. 6	Bombay and Hyderābād ...	1,261	23·6	12·5	
		S	No. 7	Madras ...	5,227	31·8	9·5	
		E	No. 10	Upper and Lower Burma ...	2,220	19·9	6·0	5·0
		E	No. 11	Lower Burma ...	1,382	18·0	6·0	15·0
		E	No. 12	Assam ...	1,805	21·9(*a*)	1·0	20·0
1-inch .	Re-survey .	N	No. 4	United Provinces and Nepāl ...	800	27·0	15·0	13·0
1-inch .	Revision Survey .	N	No. 2	Punjab and Rājputāna ...	1,043	58·0	4·0	5·0
		N	No. 3	United Provinces ...	2,152	26·5	8·0	
		N	No. 4	United Provinces and Nepāl ...	802	42·7	11·5	9·6
		E	No. 10	Upper Burma ...	65	32·9	5·0	
1-inch .	Supplementary Survey .	S	No. 7	Madras ...	715	49·1	4·8	
1½-inch .	Survey .	S	No. 6	Hyderābād ...	30	8·5	39·5	
2-inch .	Survey .	N	No. 3	United Provinces ...	391	10·7	16·5	
		S	No. 5	Berār and Central Provinces ...	64	6·6	20·0	30·0
		S	No. 7	Madras ...	60	4·9	88·7	
		E	No. 10	Upper Burma ...	222	5·8	10·0	42·0
		E	No. 11	Ditto. ...	285	4·9	14·0	44·0
		E	No. 12	Assam ...	474(*b*)	6·6(*a*)	...	62·0
4-inch .	Military Survey .	N	No. 1	North-West Frontier Province ...	64	7·2	37·0	
4-inch .	Survey (special forest) .	N	No. 3	United Provinces ...	50	2·0	133·5	
		E	No. 11	Upper Burma ...	128	2·9	22·0	96·0

(*a*) Training section excluded from average.
(*b*) Includes 1·54 square miles of unreserved land.

Digitized by Google

TABLE I.—*Concluded.*

OUT-TURNS OF DETAIL SURVEY.—*Concluded.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	Out-turn, square miles.		Average number of fixings per square mile.	
					Total.	Average per man per month of 24 working days.	*In situ* (by resection).	Plane-table traverse.
4-inch .	Supplementary Survey (special forest)	N	No. 3	United Provinces ...	495	35·0	20·8	
16-inch.	Survey .	N	No. 20	Sanāwar, Kālka, Fort Lockhart, Hangu and Thal ...	1·82	0·38		5·69
16-inch.	Re-survey .	N	No. 20	Peshāwar, Rāwalpindi, Bakloh, Jullundur, Bannu, Jhelum, Siālkot and Topa	27·77			50·12
64-inch.	Re-survey .	N	No. 20	Peshāwar, Rāwalpindi, Bakloh, Jullundur and Bannu Bazaars ...	0·54	0·03		3·27
125 feet to 1 inch.	Survey .	N	No. 20	Simla (N.I. Lines)	1 (*a*)			
125 feet to 1 inch.	Supplementary Survey	N	Simla Survey Detachment	Simla ...	1,050·0 (*a*)	63·0 (*a*)		4·5 (per acre)

(*a*) Acre or acres.

Digitized by Google

TABLE II.
DETAILS OF TRIANGULATION AND TRAVERSING.

Scale.	Class of Survey.	Circle.	Party.	Locality.	TRIANGULATION.									TRAVERSING.				
					Instrument used; diameter in inches.	Area in square miles.	Square miles to each point fixed.	Square miles to each height.	Stations fixed.	Triangular error in seconds.	Linear error per mile in feet.	Intersected Points. Number of points fixed.	Intersected Points. Linear error per mile in feet.	Area in square miles.	Linear miles of chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
4-inch .	Triangulation and Traversing.	N	No. 1	Peshāwar District, North-West Frontier Province	6	16	0·57	0·57	...	...	...	28	0·53	...	15·3	46	3·6	1·4
½-inch .	Triangulation and Traversing.	N	No. 2	Rājputāna ...	6	1260	5·5	6·0	30	12·8	0·6	198	0·9	800	312·6	525	4·01	0·39
1-inch .	Triangulation	N	No. 3	United Provinces ...	6	149	1·8	1·8	7	12·7	0·368	65	0·450	...	...	...	...	...
		N	No. 3	Ditto ...	6	336	1·7	1·7	9	10·3	0·152	180	0·656	...	...	...	...	...
4-inch .	Triangulation	N	No. 3	Ditto ...	6	260	0·24	0·24	64	8·4	0·166	990	0·475	...	...	...	...	...
1-inch .	Traversing .	N	No. 3	Ditto ...	5	...	...	...	...	...	...	...	...	...	454	1,732	7	1
4-inch .	Traversing .	N	No. 3	Ditto ...	5	...	...	...	...	...	...	...	...	...	512	8,178	5	4
1-inch .	Triangulation	N	No. 4	United Provinces and Nepāl ...	6	107	4·3	4·3	5	12	1·3	20	1·5	...	...	...	...	...
16-inch .	Triangulation and Traversing	N	No. 20	Rāwalpindi, Topa, Bakloh, Nīmach, Jhelum and Siālkot. ...	6	64	...	...	11	16	1	...	...	23·87	340·09	3,193	9	1·41
		N	No. 20	Chaman, Hangu, Fort Lockhart and Thal ...	6	30	...	...	12	9	1	...	...	4·83	41·16	224	10	0·69

Digitized by Google

TABLE II.—*concluded.*

DETAILS OF TRIANGULATION AND TRAVERSING.—*concluded.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	TRIANGULATION.									TRAVERSING.				
					Instrument used; diameter in inches.	Area in square miles.	Square miles to each point fixed.	Square miles to each height.	Stations fixed.	Triangular error in seconds.	Linear error per mile in feet.	Intersected Points. Number of points fixed.	Intersected Points. Linear error per mile in feet.	Area in square miles.	Linear miles of chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
½-inch and 1-inch	Survey and Revision Survey	S	No. 5	Central India and Central Provinces ...	6	3,853	10·6 (*a*)	10·6 (*a*)	45	7·8	0·13	317	(*b*)					
½-inch, 1-inch and 1½-inch	Survey .	S	No. 6	Bombay and Hyderābād	5 & 6	13,961	5·7	5·7	252	9·2	0·19	2,215	0·60					
1-inch and 2-inch	Survey and Supplementary Survey	S	No. 7	Madras	6	10,041 9,874	(*b*)	(*b*)	196	7·0	0·14	(*b*)	(*b*)					
4-inch .	Special Forest Survey	S	No. 7	Do.	6	167	0·5	0·5	36	6·7	0·13	320	0·47					
1-inch .	Survey .	S	No. 8	Do.	6	3,825	6·3	6·3	78	7·2	0·16	525	0·55					
1-inch	Survey	E	No. 9	Bengal	...	...	...	...	...	...	...	...	...	1,504	682	1,589	5	0·9
½-inch	Survey	E	No 10	Upper Burma ...	6	2,000	14·4	14·7	14	6·2	0·1	112	0·3	...	...	...	...	...
1-inch	Survey	E	No. 11	Lower Burma ...	6	580	8·3	8·3	6	7·0	0·1	59	0·3	...	...	...	...	...
1-inch and 2-inch	Survey	E	No. 12	Assam	...	...	...	...	...	...	...	...	...	1,850	884	5,875	3·2	2·1

(*a*) Additional intersected points, previously fixed by triangulation, are available.
(*b*) Computations not completed.

Digitized by Google

TABLE III.

COST-RATES OF SURVEY.

Circle.	Party.	Locality.	COST-RATE, RUPEES, PER SQUARE MILE.													COST-RATE, RUPEES.				Total survey out-turns on all scales, square miles.	Total cost of party. Rs.	Remarks.
			¼-inch survey.	½-inch survey.	1-inch survey.	1-inch re-survey.	1-inch revision survey.	1-inch supplementary survey.	1½-inch survey.	2-inch survey.	4-inch survey.	4-inch supplementary survey.	16-inch survey.	64-inch survey.	125 feet to 1 inch special survey.	Triangulation per square mile.	Traversing per linear mile. Topographical.	Traversing per linear mile. Forest boundary.	Fair drawing, per square mile.			
N	No. 1	Kashmīr and Jammu .	13·3	...	17·4	...	...	...	...	...	...	...	...	...	...	...	...	...	11·8	703	69,416 (a)	(a) Excludes Rs. 841 for Bīkaner traverse and Rs. 619 for Tharoch forest survey or a total of Rs. 1,460 which will be recovered from the States concerned and refunded.
		Peshāwar District, North-West Frontier Province	...	...	...	...	...	...	...	...	135·9	...	...	...	...	...	15·1	...	40·0			
N	No. 2	Punjab and Rājputāna	...	...	7·6	...	8·4	...	...	...	...	...	...	...	...	6·6	9·0	...	3·2	2,645	62, 944(b)	(b) Excludes Rs. 445 on account of cost of survey and mapping done for the Executive Engineer, Lower Bāri Doāb Canal, Baloke, Punjab, which will be recovered and refunded.
N	No. 3	United Provinces .	...	...	...	...	16·8	...	...	19·5	154·2	8·4	...	...	...	* 6·4 †28·3	16·7	27·1	4·7	3,088	1,10,334 (c)	(c) Includes Rs. 32,714 on account of cost of forest survey debitable to Rāmnagar and Kumaun Forests, United Provinces. * For 1-inch detail survey. † For 4-inch forest survey.
N	No. 4	United Provinces and Nepāl . . .	...	...	46·9	8·7	5·3	...	..	...	...	...	...	...	...	65·3	...	...	3·6	1,732	51,010	
N	No. 20	Peshāwar, Rāwalpindi, Bakloh, Jullundur, Sanāwar, Simla (N. I. Lines), Kālka, Fort Lockhart, Hangu, Thal, Bannu, Jhelum, Siālkot, Upper and Lower Topa, Chaman and Nimach. . . .	...	...	...	...	...	...	...	...	...	...	‡ 1·41	‡ 9·44	...	‡ 0·03	‡ 0·70		‡ 0·46	30	53,485	‡ Per acre.

Digitized by Google

TABLE III—*concluded.*

COST-RATES OF SURVEY—*concluded.*

Circle.	Party.	Locality.	COST-RATE, RUPEES, PER SQUARE MILE.													COST-RATE, RUPEES.				Total survey out-turns on all scales, square miles.	Total cost of party. Rs.	REMARKS.
			¼-inch survey.	½-inch survey.	1-inch survey.	1-inch re-survey.	1-inch revision survey.	1-inch supplementary survey.	1½-inch survey.	2-inch survey.	4-inch survey.	4-inch supplementary survey.	16-inch survey.	64-inch survey.	125 feet to 1 inch special survey.	Triangulation per square mile.	TRAVERSING PER LINEAR MILE. Topographical.	TRAVERSING PER LINEAR MILE. Forest boundary.	Fair drawing, per square mile.			
N	Simla Survey Detachment	Simla . .	...	...	...	..	...	...	...	...	...	...	...	...	*15·8	...	...	...	*2·0	1,050 acres	24,094	* Per acre.
S	No. 5	Berār, Central India and Central Provinces	..	...	...	...	...	...	...	43·0	...	...	...	...	...	3·2	...	...	...	64	15,259 (*d*)	(*d*) Excludes Rs. 15,420, cost of ¼-inch mapping.
S	No. 6	Bombay and Hyderābād	...	4 5	10·5	...	...	...	66·3	...	...	...	...	...	...	3·7	...	...	1·8	11,177	1,31,724	
S	No. 7	Madras . .	...	...	8·5	...	...	6·5	...	65·8	...	...	...	...	...	3·2† 29·8‡	...	...	3·9	6,002	1,12,848	† For 1-inch. ‡ For 4-inch.
S	No. 8	Do. . .	...	...	...	...	...	...	...	...	...	...	...	...	...	4·4	...	...	...	...	20,034(*e*)	(*e*) Excludes Rs. 20,615, cost of ¼-inch mapping.
E	No. 9	Bengal . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17	...	7·3	...	53,120	
E	No. 10	Upper and Lower Burma	...	8·6	41·8	...	7·7	...	...	90·5	..	...	...	...	...	6·2	...	...	8·5	2,857	1,54,892	
E	No. 11	Do. .	...	...	50·7	...	...	...	...	78·4	142·9	...	...	...	...	4·5	...	...	8·6	1,795	1,22,697(*f*)	(*f*) Excludes Rs. 15,394 on account of Maymyo Drawing Office but includes Rs. 18,296 expenditure on special forest survey debitable to Forest Department.
E	No. 12	Assam . .	...	...	28·3	...	...	...	...	71·1	...	...	...	...	...	...	23·9	...	10·2	2,279	1,32,761	

Digitized by Google

Digitized by Google

PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

TRIGONOMETRICAL SURVEY.

ASTRONOMICAL LATITUDES.

PERSONNEL of No. 13 PARTY

Imperial Officers.

From 1st October 1915 to 12th September 1916 the Superintendent of the Trigonometrical Survey held charge in addition to his other duties.

Major G. A. Beazeley R. E., in charge 13th to 24th September 1916.

Major H. H. Turner R. E., in charge 25th to 30th September 1916.

Lower Subordinate Service.

2 Computers, etc.

As no officer was available no Latitude Operations were undertaken and the *personnel* of the party was employed at the Head Quarters Offices. Progress was made with the marking of the Longitude stations by means of suitably inscribed slabs. Up to the end of September 1916 the following stations have been marked:—

Agra, Akyab, Amritsar, Bangalore, Bellary, Deesa, Fyzabad, Jalpaiguri, Jubbulpore, Karachi and Nagarkoil.

PENDULUM OPERATIONS.

PERSONNEL of No. 14 PARTY

Imperial Officers.

The Superintendent of the Trigonometrical Survey held charge in addition to his other duties.

Lower Subordinate Service.

2 Computers, etc.

As no officer was available no pendulum work was undertaken and the *personnel* of the party was employed at the Head Quarters Offices.

Digitized by Google

Digitized by Google

TRIANGULATION

By J. de Graaff Hunter, M. A.

Personnel of No. 15 PARTY.

Imperial Service.

J. de Graaff Hunter, Esq., M. A., in charge.

Provincial Service.

Mr. L. Williams.
„ G. A. Norman.

Upper Subordinate Service.

Mr. Jugal Behari Lal.

Lower Subordinate Service.

16 Computers, etc.

No new triangulation was undertaken during the season 1915-16, but one detachment was employed in revising the southern triangle* of the Manipur Meridional Series, which when observed at the end of season 1901-02 exhibited a large triangular error. This detachment consisted of :—

Mr. L. Williams in charge.
Mr. Jugal Behari Lal.

Note—Mr. G. A. Norman's services were lent to the Superintendent Northern Circle till the 15th September 1916, on which date he was transferred to No. 17 Party and Mr. Jugal Behari Lal was transferred to No. 19 Party from the 1st August to 17th September 1916.

Principal Triangulation.

No. of stations observed at	4
„ „ newly built and fixed	Not shown as work was only revisionary.
Length of triangulation completed in miles	
„ „ remaining to be done ...	
Area „ „ in miles	
No. of triangles observed	2
No. of Astronomical Azimuths observed	2
„ „ Latitudes observed	2
Maximum triangular error	0″·647
Average „ „	0″·641
Mean closing error in latitude	Not shown as work was only revisionary.
„ „ „ „ longitude	
„ „ „ „ height	
„ „ „ „ azimuth	
„ „ „ „ log side unit being the seventh place of decimals.	
Theodolite used	T. & S. 12-inch micrometer No. 11.

The revision of the observations of the southern triangle of the Manipur Meridional Series was important as it formed the connection between this series and the Burma Coast Series, and it was necessary to ensure an accurate connexion before the final adjustment of the triangulation could be taken up.

The stations, at which observations were retaken, are situated on the western spurs of the Arakan Yomas in the Akyab and Kyaukpyu districts of Lower Burma. The country is of a most difficult nature being cut up by innumerable creeks and great difficulties were encountered in the matter of transport and supplies.

* *Vide* Index Map No. 14.

Digitized by Google

The two stations of the Burma Coast Series on which the Manipur Meridional Series had previously been closed were found destroyed. One of these stations Rongdong H.S. was rebuilt with the aid of the auxiliary marks but the old position of the second station Angrantaung (Ingrantaung) H. S. could not be satisfactorily determined and a new station was built on the site. It was therefore necessary to carry the observations down to a third station Rankhamao (Retkamauk) H. S. of the Burma Coast Series so as to ensure a thoroughly satisfactory connection.

The triangles were observed with Troughton and Simm's 12-inch theodolite No. II and the average triangular error was 0".64. This is satisfactory considering that the stations were unfavourably situated, several rays grazing badly over intervening hill ranges with the result that the helios and lamps were most unsteady and difficult to intersect accurately.

An opportunity was taken during the course of this work to carry out some astronomical observations. Two astronomical azimuths and two astronomical latitudes were observed, the results of which are summarised below, together with those previously obtained at the adjacent station of Dattaung.

The latitudes were observed on the circum-meridian plan and the results show a very satisfactory degree of precision, the probable errors being 0".19 and 0".13 respectively. The probable error of a single observation in each case was 2".0.

Astronomical Latitudes and Azimuths.

Name of station		Latitude		Longitude		Height in feet	Deflection of plumb-line. Positive values indicate westerly or southerly deflection.		
							A − G (in meridian)	A − G cot λ (in prime vertical)	
Yeponetaung	H.S.	20°	15′	93°	42′	2819	−4".17 [−6".0]	−24".4 [−16".6]	About 20 miles inland from Burma Coast with high ranges to north and south.
Ret-ka-mauk	H.S.	19	48	93	28	1585	−1".28 [−3".3]	− 9".2 [− 1".4]	On an island practically on coast line.
Dattaung	H.S.	20	13	93	1	...	+2".0 [+0".2]	−10".3 [− 5".0]	Adjusted on the Akyab Electro-telegraphic longitude results.
							Values in square brackets are in terms of most recent spheroid. (Helmert)		

The values of the latitudes, longitudes and azimuths of the stations are in final terms of the Burma Coast Series computed from the finally adjusted values of the Indian Triangulation. These values will be slightly modified when the Burma triangulation is adjusted as a whole.

Azimuth Observations.—A correction of +2".2 is necessary to close these results on the longitude arcs (*vide* G.T.S. Volume XVIII Appendix S.) giving corrected results of −22".2 and −7".0 respectively on the Everest Spheroid. Expressed in terms of the latest spheroid a further quantity 5".6 has to be added giving the final results −16".6 and −1".4 respectively. It is worthy of note that the station Retkamauk situated on an island near the coast with open sea to the west and mountainous country to the east shows only a very slight inland (eastward) deflection, whereas the station Yeponetaung which is 20 miles inland has a deflection of 16".6 eastward. This is comparable with the eastward deflection found at coast stations in India *e.g.*, Madras, Mangalore.

Digitized by Google

TIDAL OPERATIONS

By Khan Bahadur Syed Aulad Hossein.

Personnel of No. 16 PARTY.

Provincial Officers.

Mr. H.G. Shaw, in charge from 11th January 1916 to 17th February 1916.

Khan Bahadur Syed Aulad Hossein, in charge till 10th January 1916 and again from 18th February 1916 to end of the year.

Mr. Syed Zille Hasnain.

Lower Subordinate Service.

20 Computers &c.

Tidal registrations by means of self-registering tide-gauges were continued during the year under report at the following ports*:—

Aden, Karāchi, Apollo Bandar (Bombay), Prince's Dock (Bombay), Madras, Kidderpore, Rangoon, Moulmein and Port Blair. This work was carried out under the direction of this department, but the immediate control of all the tidal observatories was entrusted to the local officers of the ports concerned.

In addition to the automatic tidal registrations at the above ports, readings of high and low water were taken during day-light on tide-poles at Bhaunagar, Akyab and Chittagong throughout the year for the purpose of checking the corresponding predictions which were based on observations taken some years ago.

List of Tidal Stations.

The following is a complete list of the ports at which tidal observations have been carried out from the commencement of the tidal operations in 1874 up to the present time. The permanent stations are shown in italics; the others are minor stations which were closed on the completion of the requisite registrations.

Serial No.	Stations.	Automatic or Personal observations.	Date of commencement of observations.	Date of closing of observations.	Number of years of observations.	Remarks.
1	Suez . . .	Automatic .	1897	1903	7	
2	Perim . . .	" .	1898	1902	5	
3	*Aden* . . .	" .	1879	Still working	37	
4	Maskat . . .	" .	1893	1898	5	
5	Bushire . . .	" .	1892	1901	8	
6	*Karāchi* . . .	" .	1868 1881	1880 Still working	13 36 } 49	† Small tide-gauge working.
7	Hanstal . . .	" .	1874	1875	1	Tide-tables not published.
8	Navānar . . .	" .	1874	1875	1	
9	Okha Point . .	" .	1874 Restarted 1904	1875 1906	1 1 } 2	Year 1904-05 is excluded.
10	Porbandar . .	Personal .	1893	1894	2	
10A	Porbandar . .	Automatic .	1898	1902	2	Years 1898, 1899 and 1902 are excluded.
11	Port Albert Victor (Kāthiāwār).	Personal .	1881	1882	1	
11A	Port Albert Victor (Kāthiāwār).	Automatic .	1900	1903	4	
12	Bhaunagar . .	" .	1889	1894	5	
13	*Bombay (Apollo Bandar).*	" .	1878	Still working	38	
14	*Bombay (Prince's Dock).*	" .	1888	"	28	
15	Marmagao (Goa) .	" .	1884	1889	5	
16	Kārwār . . .	" .	1878	1883	5	
17	Beypore . . .	" .	1878	1884	6	
18	Cochin . . .	" .	1886	1892	6	

* *Vide* Index Map No. 14.

Digitized by Google

Serial No.	Stations.	Automatic or Personal observations.	Date of commencement of observations.	Date of closing of observations.	Number of years of observations.	Remarks.
19	Tuticorin	Automatic	1888	1893	5	
20	Minicoy	"	1891	1896	5	
21	Galle	"	1884	1890	6	
22	Colombo	"	1884	1890	6	
23	Trincomalee	"	1890	1896	6	
24	Pāmban Pass	"	1878	1882	4	
25	Negapatam	"	1881	1888	5	Years 1883 to 1885 are excluded.
26	*Madras*	"	1880 Restarted 1895	1890 Still working	10 21 } 31	
27	Cocanāda	"	1886	1891	5	
28	Vizagapatam	"	1879	1885	6	
29	False Point	"	1881	1885	4	
30	Dublat (Sāgar Island)	"	1881	1886	5	
31	Diamond Harbour	"	1881	1886	5	
32	*Kidderpore*	"	1881	Still working	35	
33	Chittagong	"	1886	1891	5	
34	Akyab	"	1887	1892	5	
35	Diamond Island	"	1895	1899	5	
36	Bassein (Burma)	"	1902	1903	2	
37	Elephant Point	"	1880 Restarted 1884	1881 1888 }	5	Year 1880-81 is excluded.
38	*Rangoon*	"	1880	Still working	36	
39	Amherst	"	1880	1886	6	
40	*Moulmein*	"	1880 Restarted 1909	1886 Still working	6 7 } 13	
41	Mergui	"	1889	1894	5	
42	*Port Blair*	"	1880	Still working	36	

Working of the Observatories.

All the tidal observatories, except Madras, were inspected by Mr. Syed Zille Hasnain during the year.

The inspection of the tidal observatory at Madras was carried out by Mr. H.G. Shaw.

In the course of the inspection of each observatory the level of the bed plate of the tide-gauge with reference to the bench-mark of reference was carefully tested by means of spirit levelling; the working zero of the tide-gauge was determined by a series of observations during rising and falling tides and compared with the true or adopted zero; the zero of the graduated staff was tested with reference to the zero of the tide-gauge; all the instruments were thoroughly overhauled, cleaned and put in perfect working order and adjustment; the observatory well was cleaned and free communication between it and the sea was restored; the observatory cabin was examined and arrangements were made for any repairs, if necessary.

The following remarks regarding each observatory may be added:—

Aden.—The driving clock of the tide-gauge stopped several times owing to bad weather, but on each occasion the interruptions in the tidal registrations were only of a few hours duration. The Inspecting Officer found that the inlet hole of the observatory well which was originally one inch in diameter had, by action of the sea, become nearly twice as large, in consequence of which the water was allowed to pass in and out of the well too freely and the registrations of the tidal curves on the diagrams were considerably distorted.

Digitized by Google

He reported the matter at once to the Chief Engineer of the Port Trust who had the above defect remedied by having the inlet hole reduced to its original size.

Karāchi.—The tidal registrations at this observatory were interrupted more than once owing to the communication hole between the sea and the observatory well being accidentally blocked for short intervals. The tide-gauge has, on the whole, worked satisfactorily.

Bombay (*Apollo Bandar*).—During the past year there has been only one interruption of a few hours in the registrations of the tide-gauge owing to the stoppage of the driving clock. With this exception, the gauge has worked very satisfactorily. At the time of the inspection the graduations on the lower portion of the graduated staff were found to have become very indistinct. The staff was removed and a new staff properly painted was fixed in its place.

Bombay (*Prince's Dock*).—The tide-gauge at this observatory has behaved slightly better than last year. The tidal registrations were stopped 8 times during the year under report, the disturbing cause being the stoppage of the clock or the breaking of the pencil wire. The longest interruption was for 16 hours.

Madras.—There have been no breaks in the working of the tide-gauge during the year. Owing to the force of the waves the graduated staff fixed on the harbour wall close to the observatory was twice dislocated. Arrangements have now been made by the harbour Engineers to have it more permanently fixed.

Kidderpore.—The working of the tide-gauge has been satisfactory. The observatory cabin has been in constant need of repairs for some years past and the piles on which it stands are badly eaten away. Moreover, there has been continual trouble in keeping the bottom of the observatory well clear owing to shallowing at the present site. These facts were brought by the Inspecting Officer to the notice of the Deputy Conservator of the Port for the last two or three years. The Port authorities have consequently decided to build a new tidal observatory in deeper water close to the iron jetty at the Kidderpore Dock head at a short distance from the present observatory. The site of the new observatory was inspected by the Inspecting Officer in January last and the plans of the building have since been received and passed by the Superintendent of the Trigonometrical Survey. The Deputy Conservator of the Port now reports that the new observatory may be expected to be completed in January 1917.

Rangoon.—The tide-gauge at this observatory has worked very satisfactorily during the past year, no interruptions having occurred in its registrations. As mentioned in last year's report, the length of the iron cylinder of the observatory was reduced by four feet to allow of a greater clearance between the bottom of the well and the river bed. This arrangement has had the desired effect. When the Inspecting Officer visited the observatory in February last he found the bottom of the well perfectly clear of mud and the communication between the river and the well quite free.

The observatory cabin was found to be in need of some repairs. The matter was brought to the notice of the Deputy Conservator of the Port who did the needful.

Moulmein.—Tidal registrations at this observatory have been continuous and satisfactory. The Inspecting Officer found that some mud had collected on the outside of the cylinder which, if allowed to accumulate, might have interfered with the free communication between the sea and the observatory well. He had it thoroughly cleared.

The graduated staff was found to have slightly sunk. It was removed and refixed at proper level, so that its zero was identical with the zero of the tide-gauge.

Port Blair.—The tide-gauge at this observatory has, as usual, worked in a very satisfactory manner. The observatory was only built last year and every thing connected with it was found to be in a very neat and tidy condition.

Computations and Reduction of Observations.

All the computations pertaining to past year's work have been completed and there are no arrears. The tidal observations at the nine working stations for the year 1915 have been reduced by harmonic analysis and the values for the tidal constants thus determined are shown in the attached tables.

These tables give the amplitudes (R) and the epochs (ζ) at the various stations; they also give the values of H and K which are connected with R and ζ in such a way, through the various astronomical quantities involved in the positions of the sun and the moon, that if the tidal observations were consistent from year to year H and K would come out the same from each year's reductions.

Digitized by Google

1915.

Tide symbol	ADEN				KARACHI				BOMBAY (Apollo Bandar)			
	$A_0 = 5 \cdot 951$ feet				$A_0 = 7 \cdot 318$ feet				$A_0 = 10 \cdot 247$ feet			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·109	174·62	0·109	174·62	0·096	185·95	0·096	185·95	0·076	191·37	0·076	191·37
S_2	0·677	244·43	0·677	244·43	0·963	325·20	0·963	325·20	1·569	5·06	1·569	5·06
S_4	0·005	237·88	0·005	237·88	0·014	3·60	0·014	3·60	0·022	203·23	0·022	203·23
S_6	0·005	200·41	0·005	200·41	0·009	320·19	0·009	320·19	0·006	136·47	0·006	136·47
S_8	0·002	309·09	0·002	309·09	0·002	49·76	0·002	49·76	0·003	130·10	0·003	130·10
M_1	0·056	75·44	0·043	40·49	0·051	81·82	0·039	47·61	0·076	97·77	0·059	63·75
M_2	1 519	229·46	1·563	226·19	2·504	296·82	2·576	295·04	3·860	332·59	3·971	331·20
M_3	0·019	35·50	0·020	210·60	0·048	139·28	0·050	316·61	0·063	210·47	0·066	28·39
M_4	0·004	301·70	0·004	295·16	0·039	337·71	0·041	334·15	0·103	333·51	0·109	330·75
M_6	0·003	333·44	0·003	323·63	0·042	211·51	0·046	206·16	0·014	75·30	0·015	71·15
M_8	0·001	254·06	0·001	240·98	0·005	238·00	0·005	230·87	0·004	325·78	0·004	320·25
O_1	0·764	237·39	0·665	36·94	0·780	246·22	0·680	47·31	0·762	247·65	0·664	49·16
K_1	1·425	199·78	1·305	34·86	1·445	211·84	1·324	46·86	1·511	211·15	1·384	46·15
K_2	0·236	25·22	0·190	235·92	0·330	105·84	0·265	316 42	0·558	141·17	0·448	351·71
P_1	0·427	220·89	0·427	30·96	0·416	232·01	0·416	42·13	0·431	233·41	0·431	43·55
J_1	0·142	321·26	0·125	36·01	0·127	331·94	0·112	45·83	0·141	338·12	0·124	51·78
Q_1	0·201	120·07	0·175	42·04	0·200	129·95	0·175	54·27	0·200	134·27	0·174	59·22
L_2	0·054	188·90	0·044	233·78	0·110	268·74	0·090	314·31	0·135	295·43	0·110	341·19
N_2	0·420	106·65	0·432	225·81	0·600	159·60	0·617	281·05	0·949	195·87	0·976	317·95
ν_2	0·058	314·86	0·060	184·49	0·090	359·23	0·093	231·04	0·125	24·49	0·128	256·88
μ_2	0·054	194·61	0·057	188·07	0·049	268·46	0·052	264·89	0·174	318·78	0·184	316·02
T_2	0·080	242·24	0·080	243·79	0·110	317·01	0·110	318·62	0·207	0·98	0·207	2·61
$(MS)_4$	0·016	160·75	0·017	157·48	0·044	323·81	0·045	322·03	0·101	49·13	0·104	47·75
$(2SM)_2$	0·021	134·43	0·022	137·70	0·024	122·26	0·024	124·05	0·032	107·06	0·033	108·45
$2N_2$	0·086	325·45	0·089	207·05	0·071	11·42	0·073	256·10	0·089	68·56	0·091	314·06
$(M_2N)_4$	0·015	129·65	0·016	245·54	0·035	214·37	0·037	334·03	0·014	226·77	0·015	347·44
$(M_2K_1)_3$	0·024	87·09	0·023	278·90	0·060	183·80	0·057	17·03	0·007	155·23	0·007	348·84
$(2M_2K_1)_3$	0·015	226·12	0·014	24·50	0·024	261·52	0·023	62·94	0·052	275·77	0·051	78·00
Long Period		°		°		°		°		°		°
Mm	0·009	347·83	0·010	225·39	0·023	31·72	0·026	268·50	0·043	332·57	0·048	209·13
Mf	0·054	146·12	0·040	3·76	0·016	99·05	0·012	315·08	0·050	143·60	0·037	359·20
MSf	0·007	56·68	0·007	59·95	0·034	203·66	0·035	205·44	0·026	119·43	0·027	120·81
Sa	0·335	77·18	0·335	357·12	0·114	113·67	0·114	33·54	0·163	33·48	0·163	313·34
Ssa	0·134	291·55	0·134	131·42	0·079	316·97	0·079	156·71	0·106	3·65	0·106	203·36

Digitized by Google

1915.

Tide symbol	BOMBAY (Prince's Dock). $A_0 = 8 \cdot 283$ feet				MADRAS. $A_0 = 2 \cdot 329$ feet				KIDDERPORE. $A_0 = 10 \cdot 453$ feet			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·098	191·41	0·098	191·41	0·030	86·12	0·030	86·12	0·086	191·61	0·086	191·61
S_2	1·619	5·07	1·619	5·07	0·465	268·95	0·465	268·95	1·573	97·38	1·573	97·38
S_4	0·022	215·91	0·022	2 5·91	0·003	267·96	0·003	267·96	0·095	117·08	0·095	117·08
S_6	0·003	173·89	0·003	173·89	0·001	122·01	0·001	122·01	0·002	16·70	0·002	16·70
S_8	0·001	16·70	0·001	16·70	0·002	328·39	0·002	328·39	0·002	263·99	0·002	263·99
M_1	0·075	96·52	0·058	62·50	0·028	38·20	0·021	4·43	0·067	100·33	0·051	66·83
M_2	3·976	332·54	4·090	331·15	1·065	239·60	1·096	238·72	3·756	54·32	3·864	53·98
M_3	0·067	215·38	0·069	33·31	0·003	195·95	0·003	14·63	0·058	100·39	0·060	279·88
M_4	0·106	340·19	0·112	337·42	0·013	195·42	0·013	193·66	0·703	28·95	0 744	28·27
M_6	0·018	174·54	0·019	170·40	0·005	101·07	0·006	98·43	0·142	305·56	0·154	304·55
M_8	0·005	121·43	0·006	115·90	0·002	77·91	0·002	74·39	0·052	261·11	0·058	259·77
O_1	0·757	246·81	0·660	48·32	0·110	164·60	0·095	326·64	0·239	221·18	0·208	23·78
K_1	1·525	210·88	1·397	45·88	0·330	140·37	0·303	335·35	0·455	218·75	0·417	53·71
K_2	0·537	143·32	0·432	353·86	0·156	53·68	0·126	264·18	0·622	239·61	0·500	90·06
P_1	0 424	232·28	0·424	42·43	0·096	165·92	0·096	336·09	0·166	234·94	0·166	45·13
J_1	0·142	337·17	0·125	50·84	0·038	238·36	0·033	311·74	0·040	301·16	0·035	14·22
Q_1	0·202	133·77	0·176	58·73	0·007	170·54	0·006	96·28	0·030	98·86	0·026	25·47
L_2	0·130	296·61	0·106	342·36	0·047	211·13	0·038	257·12	0·190	14·72	0·156	60·96
N_2	0·963	196·74	0·991	318·80	0·244	112·46	0·251	235·29	0·727	282·64	0·748	46·30
ν_2	0·143	26·53	0·147	258·92	0·042	304·03	0·043	177·16	0·299	120·08	0·308	354·01
μ_2	0·179	314·32	0·190	311·55	0·029	159·47	0·031	157·71	0·302	172·50	0·320	171·83
T_2	0·220	0·63	0·220	2·26	0·053	243·78	0·053	245·42	0·146	111·59	0·146	113·26
$(MS)_4$	0·117	50·42	0·120	49·04	0·008	233·58	0·008	232·70	0·658	70·71	0·677	70·37
$(2SM)_2$	0·038	112·54	0·039	113·92	0·018	207·14	0·019	208·02	0·079	341·89	0·081	342·23
$2N_2$	0·077	68·32	0·079	313·83	0·053	346·77	0·054	233·31	0·185	105·23	0·190	352·90
$(M_2N)_4$	0·018	257·54	0·020	18·22	0·007	102·62	0·008	224·57	0·279	262·52	0·295	25·85
$(M_2K_1)_3$	0·004	70·64	0·004	264·26	0·016	78·13	0·016	272·23	0·159	200·07	0·150	34·70
$(2M_2K_1)_3$	0·053	286·23	0·052	88·47	0·004	166·37	0·003	329·63	0·015	172·78	0·014	337·14
Long Period		°		°		°		°		°		°
Mm	0·039	335·80	0·043	212·35	0·043	67·33	0·048	303·62	0·271	134·82	0·301	10·82
Mf	0·053	141·46	0·039	357·05	0·060	141·58	0·044	356·64	0·337	195·68	0·248	50·15
MSf	0·025	94·84	0·026	96·22	0·046	324·04	0·047	324·92	0·873	38·86	0·898	39·20
Sa	0·165	17·70	0·165	297·56	0·398	320·06	0·398	239·89	2·202	233·61	2·202	153·43
Ssa	0·100	355·80	0·100	195·51	0·308	289·32	0·308	128·99	0·667	142·46	0·667	342·09

Digitized by Google

1915.

Tide symbol	RANGOON				MOULMEIN				PORT BLAIR			
	$A_0 = 10 \cdot 410$ feet				$A_0 = 8 \cdot 449$ feet				$A_0 = 4 \cdot 933$ feet			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·132	135·80	0·132	135·80	0·113	142·38	0·113	142·38	0·036	78·50	0·036	78·50
S_2	2·204	168·06	2·204	168·06	1·546	146·59	1·546	146·59	0·979	317·03	0·979	317·03
S_4	0·103	266·78	0·103	266·78	0·077	225·37	0·077	225·37	0·005	290·17	0·005	290·17
S_6	0·007	20·35	0·007	20·35	0·009	228·16	0·009	228·16	0·004	43·92	0·004	43·92
S_8	0·002	305·22	0·002	305·22	0·003	228·99	0·003	228·99	0·001	300·26	0·001	300·26
M_1	0·065	142·69	0·050	109·45	0·041	119·04	0·031	85·85	0·029	42·51	0·023	9·16
M_2	5·756	128·95	5·922	129·14	4·115	110·41	4·233	110·70	1·939	281·59	1·995	281·56
M_3	0·034	151·43	0·036	331·72	0·039	134·35	0·040	314·79	0·007	177·58	0·008	357·53
M_4	0·472	162·22	0·500	162·62	0·898	162·81	0·950	163·40	0·006	86·12	0·007	86·05
M_6	0·225	81·91	0·245	82·50	0·053	175·18	0·058	176·06	0·006	83·54	0·006	83·43
M_8	0·075	89·91	0·084	90·69	0·049	91·14	0·054	92·32	0·003	28·44	0·004	28·30
O_1	0·345	219·61	0·301	22·77	0·277	238·52	0·241	41·78	0·169	141·37	0·147	304·28
K_1	0·733	199·21	0·671	34·15	0·488	202·40	0·447	37·34	0·445	132·43	0·407	327·38
K_3	0·796	309·80	0·640	160·21	0·526	287·88	0·423	138·29	0·311	101·93	0·250	312·36
P_1	0·180	247·78	0·180	57·99	0·141	254·78	0·141	64·99	0·127	148·33	0·127	318·52
J_1	0·055	332·04	0·049	44·79	0·036	337·93	0·032	50·63	0·055	242·97	0·049	315·86
Q_1	0·035	100·33	0·030	27·78	0·043	129·18	0·038	56·77	0·018	320·24	0·016	247·31
L_2	0·424	87·66	0·347	134·15	0·311	69·03	0·255	115·56	0·070	244·25	0·057	290·63
N_2	1·020	354·15	1·049	118·63	0·776	337·37	0·798	102·00	0·387	153·38	0·398	277·51
ν_2	0·295	204·04	0·304	78·75	0·236	196·97	0·242	71·82	0·062	330·90	0·064	205·26
μ_2	0·537	282·75	0·568	283·15	0·385	264·23	0·408	264·82	0·063	322·63	0·066	322·56
T_2	0·321	146·81	0·321	148·50	0·262	128·61	0·262	130·30	0·113	301·58	0·113	303·26
$(MS)_4$	0·455	212·67	0·468	212·86	0·766	205·57	0·788	205·87	0·006	234·69	0·006	234·65
$(2SM)_2$	0·146	44·55	0·150	44·36	0·148	30·80	0·152	30·50	0·010	118·30	0·011	118·34
$2N_2$	0·305	194·16	0·314	82·93	0·181	169·05	0·186	58·02	0·034	25·05	0·035	273·34
$(M_2N)_4$	0·188	35·25	0·199	159·93	0·348	29·82	0·368	154·75	0·010	203·20	0·010	327·29
$(M_2K_1)_3$	0·169	252·16	0·159	87·30	0·200	252·83	0·188	88·06	0·033	108·10	0·031	303·01
$(2M_2K_1)_3$	0·114	242·09	0·110	47·55	0·115	255·85	0·112	61·51	0·006	38·37	0·006	203·35
Long Period		°		°		°		°		°		°
Mm	0·189	145·99	0·210	21·70	0·359	145·10	0·398	20·76	0·028	115·35	0·031	351·19
Mf	0·239	178·07	0·176	31·96	0·422	188·82	0·311	42·61	0·074	160·87	0·055	15·01
MSf	0·369	49·64	0·380	49·44	1·163	46·38	1·197	46·09	0·016	336·99	0·016	337·02
Sa	1·194	232·17	1·194	151·96	2·208	227·40	2·208	147·19	0·125	250·29	0·125	170·09
Ssa	0·074	146·40	0·074	345·98	0·598	92·00	0·598	291·58	0·079	0·66	0·079	200·26

Digitized by Google

Data forwarded to England.

The following data were prepared and supplied to the Director, National Physical Laboratory, Teddington, England during the year under report:—

(*a*) Values of the tidal constants for 40 ports for the tide-tables for 1919, ready for use for the tide-predicting machine.

(*b*) Actual values of high and low water during 1914 at 12 stations. These include nine stations at which regular tidal observations by self-registering tide-gauges were carried out and three stations at which high and low water readings were taken during day-light on tide-poles.

(*c*) Comparisons of the above with predicted values for 1914, the errors being tabulated in such form as to be of use in improving the predictions, if possible.

Errors in Predictions.

The predicted times and heights of high and low water for the year 1915, as given in the tide-tables, have been compared against the actual values obtained from tidal observations at the nine stations now working and at three other stations where tidal registrations by self-registering tide-gauges were stopped but the times and heights of high and low water were read on the tide-poles.

The errors of the predictions thus determined are tabulated in the five tables herewith appended.

No. 1.

Percentages and amounts of the errors in the predicted times of high water at the various tidal stations for the year 1915.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	682	48	46	4	2	0
Karāchi	"	700	20	40	15	16	9
Bhaunagar	T. P.	365	69	31	0	0	0
Bombay (Apollo Bandar)	Auto.	705	46	39	8	5	2
Bombay (Prince's Dock)	"	688	44	42	8	5	1
Madras	"	704	46	44	5	4	1
Kidderpore	"	706	29	43	11	11	6
Chittagong	T. P.	365	38	44	9	7	2
Akyab	"	363	93	5	1	1	0
Rangoon	Auto.	703	48	37	6	7	2
Moulmein	"	701	28	44	13	10	5
Port Blair	"	705	36	45	8	7	4

Digitized by Google

No. 2.

Percentages and amounts of the errors in the predicted times of low water at the various tidal stations for the year 1915.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	677	47	45	5	2	1
Karāchi	"	706	29	36	13	14	8
Bhaunagar...	T. P.	365	65	35	0	0	0
Bombay (Apollo Bandar)	Auto.	703	41	41	7	7	4
Bombay (Prince's Dock)	"	686	40	42	9	7	2
Madras	"	706	42	46	7	4	1
Kidderpore	"	703	26	40	14	11	9
Chittagong	T. P.	365	42	42	6	6	4
Akyab	"	364	94	5	0	0	1
Rangoon	Auto.	703	33	36	11	12	8
Moulmein	"	700	22	42	14	13	9
Port Blair	"	706	44	42	5	5	4

No. 3.

Percentages and amounts of the errors in the predicted heights of high water at the various tidal stations for the year 1915.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	682	6·7	92	8	0	0
Karāchi	"	700	9·3	65	33	2	0
Bhaunagar...	T. P.	365	31·4	68	29	3	0
Bombay (Apollo Bandar)	Auto.	705	13·9	74	22	4	0
Bombay (Prince's Dock)	"	688	13·9	70	24	5	1
Madras	"	704	3·5	74	23	3	0
Kidderpore	"	706	11·7	47	25	14	14
Chittagong	T. P.	365	13·3	49	27	13	11
Akyab	"	363	8·3	80	17	2	1
Rangoon	Auto.	703	16·4	54	31	10	5
Moulmein	"	701	12·7	35	26	19	20
Port Blair	"	705	6·6	80	20	0	0

Digitized by Google

No. 4.

Percentages and amounts of the errors in the predicted heights of low water at the various tidal stations for the year 1915.

STATIONS.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	677	6·7	95	5	0	0
Karāchi	"	706	9 3	81	18	1	0
Bhaunagar...	T. P.	365	31·4	63	33	4	0
Bombay (Apollo Bandar)	Auto.	703	13 9	71	25	4	0
Bombay (Prince's Dock)	"	686	13·9	68	25	7	0
Madras	"	706	3 5	78	21	1	0
Kidderpore	"	703	11·7	47	29	17	7
Chittagong	T. P.	365	13·3	57	15	12	16
Akyab	"	364	8 3	74	23	2	1
Rangoon	Auto.	703	16 4	36	28	20	16
Moulmein	"	700	12·7	37	25	14	24
Port Blair	"	706	6 6	91	9	0	0

No. 5.

Table of average errors in the predicted times and heights of high and low water at the several tidal stations for the year 1915.

Stations.	Automatic or tide-pole observations.	Mean range at springs in feet.	Average Errors of time in minutes.		Average Errors of height in terms of the range.		Average Errors of height in inches.	
Open Coast.			H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
Aden	Auto.	6·7	7	7	·025	·025	2	2
Karāchi	"	9·3	15	13	·036	·027	4	3
Bhaunagar...	T. P.	31 4	5	5	·011	·011	4	4
Bombay (Apollo Bandar)	Auto.	13·9	8	10	·018	·018	3	3
Bombay (Prince's Dock)	"	13 9	8	9	·024	·024	4	4
Madras	"	3 5	8	8	·071	·071	3	3
Akyab	T. P.	8·3	1	1	·030	·030	3	3
Port Blair	Auto.	6 6	10	9	·038	·025	3	2
General Mean	...	...	8	8	·032	·029	3	3
Riverain.								
Kidderpore...	Auto.	11·7	12	14	·043	·043	6	6
Chittagong	T. P.	13·3	10	9	·038	·038	6	6
Rangoon	Auto.	16·4	8	13	·025	·036	5	7
Moulmein	"	12·7	12	15	·052	·052	8	8
General Mean ...	...	...	11	13	·040	·042	6	7

Digitized by Google

Summary for 1915.

Number of Stations.	Predictions tested by	Percentage of Predictions, at high and low water within					
		15 minutes of actuals.		8 inches of actuals.		one-tenth of mean range.	
		High.	Low.	High.	Low.	High.	Low.
6 Open coast	S. R. Tide-gauge	82	82	98	98	96	96
2 "	Tide-pole	99	100	97	97	99	99
3 Riverain	S. R. Tide-gauge	76	66	73	67	94	92
1 "	Tide-pole	81	84	76	72	96	92

Comparison of the Predictions for the year 1915 with those for the previous year.

On comparing the predictions of times and heights of high and low water at all the working stations for the year 1915 with the corresponding actual readings it appeared that the predictions for times at Aden, Madras and Moulmein and those of heights at Kidderpore and Karāchi had slightly improved since the year 1914. The predictions at other stations were practically of the same standard of accuracy as those for the year 1914.

The greatest difference between the actual and predicted heights of low water for 1915 at the riverain ports was as follows :—

Kidderpore ... 1 foot 11 inches on 27th and 28th July 1915, actuals being lower.
Rangoon ... 2 feet 5 inches on 27th October 1915, actuals being lower.
Moulmein ... 3 feet 3 inches on 24th July 1915, actuals being lower.

Tide-Tables.

The tide-tables for the year 1917 have been received from England and distributed to the various officers concerned. The tide-tables for the year 1918 are being published in England and the data for the preparation of the tide-tables for 1919 were despatched to England in April 1916.

The amount realized on the sale of tide-tables during the year ending September 1916 is Rs. 1,874-3-10.

Programme for season 1916-17.

Tidal observations during the coming year will be continued at the 9 observatories now working.

Digitized by Google

LEVELLING

By H. G. Shaw.

Personnel of No. 17 PARTY

Provincial Officers.

Mr. H. G Shaw, in charge.
" D. H. Luxa.
" T. F. Kitchen.
" Jiya Lal Sahgal, up to 31st August 1916.
" N. N. Chuckerbutty, L. C. E.

Upper Subordinate Service.

Mr. Karuna Kumar Das, up to 21st May 1916.
" Satish Chandra Mukerji.

Lower Subordinate Service.

2 Computers.
7 Recorders.
2 Clerks.

The recess office of the party closed at Mussoorie on 14th October 1915 and opened at Dehra Dūn on 21st idem. The detachments left Dehra Dūn for the field on the 4th November 1915 and returned to recess quarters at Mussoorie between the 19th April and 3rd May 1916.

Four detachments were employed in levelling operations* during the past field season. The out-turn amounted to 828 miles of "fore and back double levelling of precision" in the Punjab, the United Provinces and in the Delhi Province. The out-turn includes 24 miles in Bahāwalpur State, 24 miles in Dholpur State and 53 miles in Gwalior State. Full details of the out-turn of work are given in Table I attached.

The health of the party was on the whole good. There were a few cases of pneumonia among the Khalasis at the commencement of the field season. Mr. Kitchen was also laid up with pneumonia towards the end of the field season which necessitated Mr. Luxa taking charge of his detachment.

Levelling operations.—The work was divided among the four detachments as follows; each detachment consisted of one levelling officer, 2 recorders and 18 menials :—

Nos. 1 (A) and 1 (B) Detachments.

Mr. Chuckerbutty was in charge of No. 1 (A) and Mr. Mukerji of No. 1 (B) detachment. These two detachments worked in opposite directions

(1) Levelled from Delhi *viâ* Karnâl to Ambâla along the Grand Trunk Road. This is a new line and completes the circuit Delhi-Meerut-Ambāla-Delhi. The closing error being 0·075 of a foot in a distance of 293 miles as shown below :—

Lines		Distance in miles.	Unadjusted dynamic difference of height in feet.	Year.
From	To			
Standard B. M. at Delhi.	Standard B. M. at Meerut.	45 5	− 20·435	1912-13
Standard B. M. at Meerut.	Standard B. M. at Ambāla Cantonment.	125·4	+ 164·993	1912-13
Standard B. M. at Ambāla Cantonment.	Standard B. M. at Delhi.	121·9	− 144 633	1915-16
	Total	292·8	− 0·075	

(2) Revised the following lines :—

(*a*) From Somna to Alīgarh along the Grand Trunk Road and thence along the main road to Agra.

(*b*) From Agra to Gwalior *via* Dholpur along the Agra-Bombay Trunk Road. These lines were originally levelled in 1861-62.

(*c*) From Lucknow *via* Unao to Cawnpore by road. This line was originally levelled in 1868-69.

The discrepancies between the old and new eights of bench-marks on the above lines are given in table III appended. It will be seen that there is a large difference of about 1·8 feet in all the bench-marks from Colonel Sander's monument, $^{B.M.\ 6}_{54\ F}$, to the standard bench-mark at Gwalior, $^{B.M.\ 31}_{54\ J}$, on the Agra-Gwalior line.

* *Vide* Index Map No. 14.

Digitized by Google

The bench-mark at Colonel Sander's monument was the initial point in 1905-06 for the connection of the Standard bench-mark at Gwalior and the continuation of the line to Jhansi, and is identical with that connected in 1915-16. The evidence is strong that the point on which the staff was placed in 1861-62 is not the same as that on which it was placed. Further evidence will be available when the line from Jhansi to Cawnpore is completed.

Nos. 2 and 3 Detachments.

Mr. Kitchen was in charge of No. 2 and Mr. Jiya Lal Sahgal of No. 3 detachment. Mr. Luxa took charge of No. 2 detachment on 28th March 1916 owing to Mr. Kitchen's serious illness.

The above detachments worked in opposite directions, and levelled from Jhang *via* Fāzilka, Mandi Dabwāli, Sirsa, Hissār and Rohtak to Delhi by road, crossing by direct levelling the Sutlej and Rāvi rivers *en route*. This is a new line. It traverses numerous canals and large irrigated tracts in the Punjab and will furnish additional data for irrigation and other purposes.

This line closes the circuits (*a*) Mandi Dabwāli-Ferozepore-Lahore-Sargodha-Jhang-Mandi Dabwāli and (*b*) Delhi-Ambāla-Ferozepore-Mandi Dabwāli-Delhi, the closing errors being 0·518 and 0·373 of a foot respectively, as shown in the following tables :—

Lines. From	Lines. To	Distance in miles.	Unadjusted dynamic difference of height in feet.	Year.	Lines. From	Lines. To	Distance in miles.	Unadjusted dynamic difference of height in feet.	Year.
Circuit A.					Circuit B.				
Embedded B. M. at Mandi Dabwāli.	Standard B. M. at Ferozepore.	76·7	+ 5·343	1907-08	Standard B. M. at Delhi.	Standard B. M. at Ambāla Cantonment.	121·9	+144·633	1915-16
Standard B. M. at Ferozepore.	Standard B. M. at Lahore Cantonment.	49·4	+ 59·731	1913-14	Standard B. M. at AmbālaCantonment.	Block-stone B. M. embedded at Doraha.	57·3	− 58·814	1913-14
Standard B. M. at Lahore Cantonment.	Embedded B.M. at Ry. Rest-house Sargodha.	117·2	− 94·287	1911-12	Block-stone B. M. embedded at Doraha.	Standard B. M. at Ferozepore.	86·9	−194·140	1860-61
Embedded B M. at Ry. Rest-house Sargodha.	Embedded B.M. at Sessions House, Jhang-Maghiāna.	69·1	−108·528	1911-12	Standard B. M. at Ferozepore.	Embedded B. M. at Mandi Dabwāli.	76·7	− 5·343	1907-08
Embedded B.M. at Sessions House, Jhang-Maghiāna.	Embedded B. M. at Mandi Dabwāli.	179·5	+137·223	1915-16	Embedded B. M. at Mandi Dabwāli.	Standard B. M. at Delhi.	202·8	+113·291	1915-16
	Total	491·9	− 0·518			Total	545·6	− 0·373	

A branch-line from Fāzilka to the Standard bench-mark at Sādikganj (Bahāwalpur State) was run in order to strengthen the connection of this Standard bench-mark. It was originally connected in 1909-10 with only one old bench-mark. This connection was considered unsatisfactory, and was rejected. The present season's work reveals an unusual accumulation of difference between the two levellers in the results of the fore and back levelling, the cause of which is under investigation. The connection of the Standard is therefore still unsatisfactory.

General Notes.

In 1913-14 the new system of "fore and back double levelling" of precision on the lines laid down in the resolution passed at the 17th General Conference of the International Geodetic Association on the 25th September 1912, was first adopted and has since been employed.

Digitized by Google

The following table gives the results of the various lines which have been levelled on this new system. It will be seen that the results of the probable accidental and systematic errors are well within the prescribed limits as given in the resolution passed at the above mentioned Conference for "Levelling of High Precision".

Table showing (i) the probable accidental error and (ii) the probable systematic error, calculated according to the following formulæ taken from Departmental Paper No. 6 of 1914:—

$$\text{(i)} \quad \eta_r^2 = \frac{1}{9}\left[\frac{\Sigma\Delta^2}{\Sigma L} - \frac{\Sigma r^2}{(\Sigma L)^2} \times \Sigma\frac{r^2}{L}\right]$$

$$\text{(ii)} \quad \sigma_r^2 = \frac{1}{9\Sigma L} \times \Sigma\frac{S^2}{L}$$

η_r is the probable accidental error in the case of a group of lines, whether forming a closed mesh or not;

σ_r is the probable systematic error in the case of a group of lines, not forming a network;

L is the length of an isolated line, or a side of a polygonal mesh in the case of a network;

ΣL is the total length of a group of lines or of the network;

Δ is the discordance of the results of the fore and back levelling found between these two consecutive bench-marks;

r is the distance between these two bench-marks;

S is the total systematic discordance found for a complete line or for the side of a mesh, between the results of the fore and back levelling.

Lines.	Length.	Probable accidental error. ± 0·00416 ft. per mile.*	Probable systematic error. ± 0·00106 ft. per mile.*	Year.
	Miles.	Foot per mile.	Foot per mile.	
Jacobābād to Quetta	207·231	± 0·0037	± 0·0001	1913-14
Ferozepore to Lahore	54·991	± 0·0029	± 0·0001	1913-14
Benares to Barākar with branch-line to Belsar Lock	312·872	± 0·0024	± 0·0002	1914-15
Meerut *via* Morādābād and Bareilly to Hāthras	243·737	± 0·0024	± 0·0002	1914-15
Multān to Bahāwalpur	59·244	± 0·0023	± 0·0004	1914-15
Raichūr *via* Bāgalkot to Bijāpur ...	170·380	± 0·0028	± 0·0004	1914-15
Bellary to Gooty	57·610	± 0·0023	± 0·0010	1914-15
Fāzilka to Sādikganj	30·498	± 0·0036	± 0·0009	1915-16
Mandi Dabwāli to Fāzilka ...	53·927	± 0·0030	± 0·0010	1915-16
Mandi Dabwāli to Delhi ...	202·788	± 0·0030	± 0·0006	1915-16
Ambāla to Delhi	121·863	± 0·0023	± 0·0002	1915-16
Somna to Agra	70·355	± 0·0028	± 0·0008	1915-16
Āgra to Gwalior	77·010	± 0·0031	± 0·0007	1915-16
Lucknow to Cawnpore	50·765	± 0·0030	± 0·0004	1915-16
Fāzilka to Jhang	125·600	± 0·0029	± 0·0000	1915-16

* Limits which must not be exceeded in "Levelling of High Precision".

Digitized by Google

The probable errors of circuit-closure from the formula $E = \sqrt{(0 \cdot 004)^2 M + (0 \cdot 00034)^2 M^2}$, *deduced from the results of the Indian Geodetic Levelling, given in G. T. S. Volume XIX.*

Circuits.	Length of circuit = M.	Closing error of circuit × 0·6745 = C.	Probable error of levelling circuit = E	C − E.	$\frac{C}{E}$.
	Miles.	Foot.	Foot.	Foot.	
(A) Lahore-Rāwalpindi-Shāhpur-Sargodha-Lahore	448·0	0·3258	0·1743	+0·1515	1·87
(B) Mandi Dabwāli-Ferozepore-Lahore-Sargodha-Jhang Maghiāna-Mandi Dabwāli	491·9	0·3494	0·1894	+0·1600	1·84
(C) Delhi-Ambāla-Doraha-Ferozepore-Mandi Dabwāli-Delhi ...	545·6	0·2516	0·2077	+0·0439	1·21
(D) Delhi-Meerut-Ambāla-Delhi ...	292·8	0·0506	0·1208	−0·0702	0·42
(E) Delhi-Muttra-Hāthras-Bareilly-Meerut-Delhi	409·9	0·0580	0·1612	−0·1032	0·36
(F) Rangoon-Thazi-Magwe-Taungdwingyi-Prome-Rangoon	882·1	0·1875	0·3226	−0·1351	0·58

The above circuits have been completed since the publication of G. T. S. Volume XIX, in 1910. None of these circuits are formed by lines levelled wholly on the new system.

With the exception of the following lines all the lines forming the above circuits have been levelled since 1910-11:—

Circuit A. Line Lahore-Rāwalpindi, levelled in 1905-06.

Circuits B and C. Line Ferozepore-Mandi Dabwāli, levelled in 1907-08.

Circuit C. Line Ferozepore-Doraha, levelled in 1860-61.

Circuit E. Line Muttra-Hāthras, levelled in 1905-06.

The actual closing errors multiplied by 0·6745 are less in three circuits and greater in three, than the theoretical probable error of closure as deduced from the above formula.

The number of these circuits is so small that hardly any comparison, at present, of the quality of the new work can be made against that of the old work. The results tend to show that the quality of the old and new work are about the same.

Digitized by Google

TABLE I—*Tabular Statement of out-turn of work, season 1915-16.*

Detachment. Nos.	Lines.	Month.	Mean distance levelled in both directions. Main Line. Mls. Chs. Lks.	Extras and branch-lines. Mls. Chs. Lks.	Total. Mls. Chs. Lks.	Relevelled. Mls. Chs. Lks.	Total number of feet (mean of both directions). Rises.	Falls.	Mean number of stations at which instruments were set up in both the directions.	Number of bench-marks connected. Primary. Rock-cut. Old.	Rock-cut. New.	Protected. Old.	Protected. New.	Standard. Old.	Standard. New.	Principal stations of triangulation. Old.	Principal stations of triangulation. New.	Secondary. Embedded. Old.	Embedded. New.	Rock-cut. Old.	Rock-cut. New.	Inscribed. Old.	Inscribed. New.	P.W.D. Old.	P.W.D. New.	Railway. Old.	Railway. New.
1 (A) and 1 (B)	Ambāla-Delhi	November 1915	33 73 45	...	33 73 45	8 61 8	285·448	255·107	355	...	...	2	...	...	...	...	12	...	1	7	111	...	1	...	...
		December „	76 61 61	2 28 52	79 10 13	7 20 45	489·177	643·272	826																
		January 1916	11 13 98	...	11 13 98	1 7 23	80·455	101·306	116																
		Totals	121 69 4	2 28 52	124 17 56	17 8 76	855·120	999 685	1297	...	...	2	.	...	...	...	12	..	1	7	111		1	...	...
	Somna *via* Alīgarh to Agra	January 1916	61 65 95	...	61 65 95	1 62 87	437 628	516·950	602	...	...	2	...	...	...	10	...	...	...	12	63	...	1	...	...
		February „	8 42 44	...	8 42 44	...	73·859	66·137	84																
		Totals	70 28 39	...	70 28 39	1 62 87	511·487	583·087	686	...	...	2	...	...	...	10	...	...	...	12	63	...	1	...	..
	Agra-Gwalior	January 1916	3 65 80	...	3 65 80	..	26·691	28·892	38	...	..	1	...	1	...	5	6	2	9	10	54	...	...	14	2
		February „	50 71 41	5 78 82	56 70 23	0 48 20	660 385	565·646	662																
		March „	22 23 56	8 15 21	30 38 77	3 18 87	204·915	114·713	338																
		Totals	77 0 77	14 14 3	91 14 80	3 67 7	891·991	709·251	1038	.	...	1	...	1	.	5	6	2	9	10	54	...		14	2
	Lucknow-Cawnpore	March 1916	8 45 2	12 63 4	21 28 6	...	56·035	38 680	427	...	...	1	1	...	...	4	4	...	...	6	62	...	1	1	...
		April „	42 16 18	13 8 47	55 24 65	0 29 50	261·025	264·649	337																
		Totals	50 61 20	25 71 51	76 52 71	0 29 50	317 060	303·329	764	...	..	1	1	..	..	4	4	...	...	6	62	.	1	1	..
		Grand Totals	319 79 40	42 34 6	362 33 46	23 8 20	2575·658	2595·352	3185	...	...	6	1	1	..	19	22	2	10	35	290	...	3	15	2
2 and 3	Fāzilka-Jhang Maghiāna	November 1915	23 76 49	7 44 53	31 41 2	...	120 890	148·687	370	...	...	...	...	...	3	3	14	...	...	5	109	...	10	...	...
		December „	67 12 36	9 21 39	76 33 75	3 77 45	397·404	411·066	875																
		January 1916	34 37 34	12 19 93	46 57 27	3 32 49	163·970	196 916	454																
		Totals	125 46 19	29 5 85	154 52 4	7 29 94	682·264	756·669	1699	...	...	...	...	...	3	3	14	...	...	5	109	...	10	...	
	Fāzilka-Sādıkganj	November 1915	15 51 42	0 35 76	16 7 18	...	74·848	85·716	187	...	...	...	1	...	...	1	...	...	...	...	13	1	...	...	...
		January 1916	14 73 40	0 32 38	15 25 78	1 53 94	74·965	85·555	158																
		Totals	30 44 82	0 68 14	31 32 96	1 53 94	149·813	171·271	345	...	...	...	1	...	...	1	...	...	...	...	13	1	...	...	...
	Mandi Dabwāli-Fāzilka	November 1915	1 36 52	...	1 36 52	...	7·437	13·407	14	...	...	...	...	...	1	2	5	...	...	4	34	...	2	...	...
		January 1916	26 36 8	5 7 24	31 43 32	...	161·741	194·160	311																
		February „	1 65 60	4 5 60	5 71 20	...	2·843	1·845	55																
		March „	23 65 90	1 10 95	24 76 85	2 15 52	143·447	170·805	243																
		Totals	53 44 10	10 23 79	63 67 89	2 15 52	315·468	380·217	623	...	...	...	...	...	1	2	5	..	...	4	34	...	2	...	.
	Mandi Dabwāli-Delhi	January 1916	8 70 57	0 35 50	9 26 7	...	79·319	69·305	86	...	...	1	1	1	3	...	19	...	...	5	166	...	13	...	...
		February „	96 24 85	6 49 74	102 74 59	4 7 3	661·455	614·950	1064																
		March „	57 16 71	2 67 43	60 4 14	0 40 80	476·092	434·233	674																
		April „	40 43 25	2 62 33	43 25 58	3 52 91	251·713	251 365	465																
		Totals	202 75 38	12 55 0	215 50 38	8 20 74	1468 579	1369·853	2289	.	...	1	1	1	3	...	19	...	...	5	166	...	13	...	...
		Grand Totals	412 50 49	52 72 78	465 43 27	19 40 14	2616·124	2678·010	4956	...	...	1	2	1	7	6	38	...	...	14	322	1	25	...	...

Digitized by Google

TABLE II—CHECK-LEVELLING.

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling.			Distance from starting bench-mark.	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (check−original). The sign + denotes that the height was greater, and the sign − less in 1915-16 than when originally levelled.
Number.	Degree sheet.	Description.		Original levelling.	Date.	Check-levelling, 1915-16.	
			Miles.	Feet.		Feet.	Feet.
		Check-levelling at Jhang and between Jhang and Thatta Māhla.					
52*	44 A	Embedded, Session's House, Jhang.	0·0	0·000	1911-12	0·000	0·000
53*	„	Embedded, Jhang Railway Station.	1·0	− 1·400	1911-12	−1·401	−0·001
54*	„	Main exit passage	1·2	+ 8·435	1911-12	+8·433	−0·002
55*	„	Platform coping	1·2	+ 7·824	1911-12	+7·833	+0·009
51*	„	Culvert	0·3	+ 6·140	1911-12	+6·149	+0·009
47*	„	Coping goods platform	6·9	+16·788	1911-12	+16·848	+0·060†
$\frac{a}{46}$*	„	Main exit passage	7·1	+15·563	1911-12	+15·618	+0·055†
46*	„	Embedded, Thatta Māhla Railway Station.	7·3	+ 7·425	1911-12	+7·484	+0·059†
		Check-levelling at Mandi Dabwāli and between Mandi Dabwāli and Birang Khera.					
5	44 K	Embedded, Mandi Dabwāli Railway Station.	0·0	0·000	1907-08	0·000	0·000
6	„	Masonry pillar	0·9	+ 0·791	1907-08	+0·783	−0·008
9	„	Embedded, Birang Khera Ry. Station.	5·2	− 8·517	1907-08	−8·554	−0·037
4	„	Home signal	0·2	+ 4·035	1907-08	+4·033	−0·002
3	„	Masonry pillar	1·1	+ 3·197	1907-08	+3·201	+0·004
2	„	Railway bridge	2·7	+10·358	1907-08	+10·366	+0·008
		Check-Levelling at Delhi.					
83	53 H	Standard bench-mark, Delhi.	0·0	0·000	1906-07	0·000	0·000
84	„	Pirghaib Tower Station	0·9	+29·992	1906-07	+30·005	+0·013
85	„	Asoka's pillar	1·2	+33·437	1906-07	+33·444	+0·007
86	„	Steps	1·4	+34·941	1906-07	+34·944	+0·003
87	„	Steps	1·3	+34·222	1906-07	+34·223	+0·001
3‡	„	Bed rock	1·6	−27·271	1912-13	−27·266	+0·005
$\frac{a}{3}$‡	„	Overbridge	2·1	−28·860	1912-13	−28·854	+0 006
$\frac{b}{56}$‡	„	Platform, Kashmīr Gate	1·7	−67·807	1912-13	−67·834	−0·027
80	„	Memorial step, St. James' Church.	1·8	−57·176	1906-07	−57·186	−0·010
81	„	Flooring, St. James' Church	1·9	−58·262	1906-07	−58·271	−0·009
79	„	Stone base, Mutiny Memorial.	2·2	−60·839	1906-07	−60·844	−0·005
		Check-Levelling at Gwalior.					
28	54 J	Railway culvert No. 356	0·0	0·000	1905-07	0·000	0·000
29	„	Railway culvert No. 352	1·2	+32·733	1905-07	+32·724	−0·009
30	„	Railway culvert	1·9	+38·709	1905-07	+38·703	−0·006
32	„	Railway bridge No. 346	3·2	+49·679	1905-07	+49·653	−0·026
33	„	Railway bridge	4·2	+40·652	1905-07	+40·630	−0·022
34	„	Sithauli, Embedded	4·7	+35·438	1905-07	+35·407	−0·031

* Temporary line form numbers, not published, of Line 55 A (Sargoda-Multān).

† These differences are probably due to the large sectional difference obtained between the levellers on this section.

‡ Temporary line form numbers of Lines 62 B (Delhi-Muttra) and 62 A (Meerut-Delhi), not published.

Digitized by Google

TABLE II (*continued.*)—CHECK-LEVELLING AT AMBALA.

Discrepancies between the old and new heights of bench-marks.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	Observed heights in feet above (+) or below (−) starting bench-mark as determined by						Difference (Check—Original) The sign + denotes that the height was greater and the sign − less in check-levelling than when originally levelled.			
		Original levelling.	Date.	Check-levelling.							
				1910-11.	1912-13.	1913-14.	1915-16.	1910-11.	1912-13.	1913-14.	1915-16.
	Miles	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
901·6⋀ at St. Paul's Church, Ambāla ...	0·0	0·000	1860·61	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000
† at ditto ditto ...	0·1	+ 0·503	1906-07	+ 0·515	+ 0·512	+ 0·513	+ 0·521	+ 0·012	+ 0·009	+ 0·010	+ 0·018
Standard Bench-mark, Ambāla ...	0·1	+ 1·829	1906-07	+ 1·827	+ 1·820	+ 1·825	+ 1·825	− 0·002	− 0·009	− 0·004	− 0·004
G.T.S. ○ B.M. at Block No. 6, Station Hospital, Ambāla ...	0·4	+ 0·029	1906-07	not connected.	+ 0·077	+ 0·083	+ 0·101	not connected.	+ 0·048	+ 0·054	+ 0·072
G.T.S. ○ B.M. at Wesleyan Church, Ambāla ...	1·0	+ 3·704	1906-07	+ 3·740	+ 3·737	+ 3·757	+ 3·777	+ 0·036	+ 0·033	+ 0·053	+ 0·073
G.T.S. ○ B.M. at Block No. 3 of No. 2, Section Hospital, Ambāla.	1·2	+ 4·969	1906-07	+ 5·009	+ 5·002	+ 5·019	+ 5·033	+ 0·040	+ 0·033	+ 0·050	+ 0·064
G.T.S. ○ B.M. at Block No. 2 of No. 2, Section Hospital, Ambāla.	1·2	+ 4·103	1906-07	+ 4·139	+ 4·133	+ 4·149	+ 4·170	+ 0·036	+ 0·030	+ 0·046	+ 0·067
G.T.S. ○ B.M. at Block No. 42 R. H. A. Lines, Ambāla ...	1·9	+10·090	1906-07	+10·123	+10·114	+10·135	+10·165	+ 0·033	+ 0·024	+ 0·045	+ 0·075
G.T.S. ○ B.M. at Block No. 43 R. H. A. Lines, Ambāla ...	2·0	+11·484	1906-07	+11·498	+11·479	+11·500	+11·523	+ 0·002	+ 0·021	+ 0·016	+ 0·039
† at R. C. Church, Ambāla ...	1·0	− 3·044	1906-07	not connected.	− 3·046	− 3·030	− 3·022	not connected.	− 0·002	+ 0·014	+ 0·022
G.T.S. ○ B.M. at R. C. Church, Ambāla ...	1·1	− 3·618	1906-07	not connected.	− 3·611	− 3·595	− 3·587	not connected.	+ 0·007	+ 0·023	+ 0·031
G.T.S. ○ B.M. at N. W. end of "B" platform, Ambāla Cantonment Railway Station.	1·7	− 2·667	1906-07	− 2·620	− 2·636	− 2·622	− 2·612	+ 0·047	+ 0·031	+ 0·045	+ 0·055
G.T.S. ○ B.M. at N.W. name plate on "A" platform of Ambāla Railway Station.*	1·7	− 3·078	1906-07	not connected.	not connected.	− 3·106	− 3·139	not connected.	not connected.	− 0·028	− 0·061
G.T.S. ○ B.M. at S.E. name plate on "A" platform of Ambāla Railway Station.	1·8	− 3·532	1906-07	− 3·498	− 3·513	− 3·501	− 3·490	+ 0·034	+ 0·019	+ 0·031	+ 0·042

* This is a doubtful bench-mark, it was missing in 1912-13 and was found replaced a little away from its original site in 1913-14.

From this table it is noticed that there is evidence of progressive change of level in the Ambāla area.

Digitized by Google

TABLE III—Revision Levelling.

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected during the revisionary operations.			Distance from starting bench-mark	Difference of orthometric heights, above (+) or below (−) the starting bench-mark.			Difference (Revision—Original) The sign + denotes that the height was greater and the sign − less in 1915-16 than when originally levelled.
Number.	Degree sheet.	Description.		From published heights.	Date of original levelling.	From revision, 1915-16 (unadjusted).	
			Miles.	Feet.		Feet.	Feet.
Revision of line Alīgarh-Agra. Part of line No. 62 (Meerut-Agra).							
1	54 I	Block-stone embedded, Alīgarh.	0·0	0·000	1861-62	0·000	0·000
3*	„	Well, Alīgarh.	0·0	+ 4·628	1905-06	+ 4·621	−0·007
4	„	Railway distant signal, Alīgarh.	0·5	+ 7·260	1905-06	+ 7·264	+0·004
7	„	Standard bench-mark, Alīgarh.	1·0	+ 7·018	1905-06	+ 7·022	+0·004
6	„	Flooring, Post office, Alīgarh.	1·5	+ 1·160	1905-06	+ 1·159	−0·001
9	„	Block-stone embedded, near mile-stone 5.	7·4	− 3·289	1861-62	− 3·290	−0·001
13	„	Block-stone embedded, Hāthras.	22·3	− 19·862	1861-62	− 19·824	+0·038
20	„	Platform, Hāthras Inspection Bungalow.	22·3	− 17·474	1905-06	− 17·431	+0·043
21	„	Verandah, Hāthras City Ry: Station.	23·4	− 17·917	1905-06	− 17·874	+0·043
22	„	Embedded, Hāthras City Ry: Station.	23·5	− 20·849	1905-06	− 20·804	+0·045
14	„	Block-stone embedded, Kewalgarhi.	29·6	− 30·714	1861-62	− 30·681	+0·033
16	„	Block-stone embedded, Jowahirgarh.	36·5	− 39·988	1861-62	− 39·887	+0·101
18	„	Block-stone embedded, Khandauli.	43·6	− 50·998	1861-62	− 50·993	+0·005
19	„	Block-stone embedded, Nandlālpur.	50·2	− 61·888	1861-62	− 61·948	−0·060
37	54 E	Platform, Jumna Bridge goods shed, Agra.	52·9	− 89·814	1905-06	− 89·906	−0·092
36	„	Railway culvert, Agra.	53·2	− 89·401	1905-06	− 89·505	−0·104
35	„	Jumna Ry: bridge, 14th pier, Agra.	53·4	− 91·633	1905-06	− 91·732	−0·099
34	„	Jumna Railway: bridge 7th pier, Agra.	53·6	− 91·515	1905-06	− 91·602	−0·087
33	„	Verandah, Agra Fort Railway Station.	54·1	− 76·940	1905-06	− 77·047	−0·107
32	„	Standard bench-mark Agra	54·2	− 79·844	1905-06	− 79·985	−0·141
28	„	Drain, Agra	55·2	− 60·243	1905-06	− 60·346	−0·103
27	„	Flooring, Post Master's Bungalow, Agra.	55·5	− 53·829	1905-06	− 53·947	−0·118
33	54 I	Block-stone embedded, Agra.	56·2	− 54·871	1861-62	− 54·999	−0·128
These results point to a change of level having occurred between Kewalgarhi and Agra during the period 1861 to 1916.							
Revision of line Agra-Gwalior. Part of line No. 63 (Agra-Sironj).							
33	54 I	Block-stone embedded, Agra.	0·0	0·000	1861-62	0·000	0·000
29	54 E	Monument, Agra	0·8	− 3·693	1905-06	− 3·692	+0·001
30	„	Metcalfe Testimonial, Agra	1·1	− 2·413	1905-06	− 2·424	−0·011
38	„	Block-stone embedded, near 8½ miles from Agra.	7·6	− 4·366	1861-62	− 4·374	−0·008
1	54 F	Block-stone embedded, Birai.	14·6	− 1·337	1861-62	− 1·411	−0·074
4	„	Dholpur H. S.	39·9	+388·038	1861-62	+387·963	−0·075
8	„	Block-stone embedded, Jorā	48·6	+ 22·418	1861-62	+ 22·188	−0·230
6	„	Col: Sanders' monument	52·3	+ 30·267	1861-62	+ 28·495	−1·772†
2	54 J	Road culvert	57·4	+ 20·734	1905-07	+ 18·970	−1·764
3	„	Road bridge	57·9	+ 19·983	1905-07	+ 18·222	−1·761
4	„	Well	58·2	+ 33·034	1905-07	+ 31·265	−1·769
6	„	Platform, Banmor Railway Station.	62·1	+ 65·416	1905-07	+ 63·621	−1·795

* Originally connected in 1861-62. † See remarks in Report.

Digitized by Google

TABLE III—(*contd.*)—REVISION LEVELLING.

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected during the revisionary operations.			Distance from starting bench-mark.	Difference of orthometric heights, above (+) or below (−) the starting bench-mark.			Difference (Revision − Original). The sign + denotes that the height was greater and the sign − less in 1915-16 than when originally levelled.
Number.	Degree sheet.	Description.		From published heights.	Date of original levelling.	From revision, 1915-16 (unadjusted.)	
			Miles.	Feet.		Feet.	Feet.
		Revision of line Agra-Gwalior. Part of line No. 63 (Agra-Sironj) contd.					
7	54 J.	Rock *in situ*	63·9	+ 60·585	1905-07	+ 58·815	−1·770
8	„	Hindu monument	66·0	+ 63·148	1905-07	+ 61·383	−1·765
9	„	Culvert	68·5	+ 90·199	1905 07	+ 88·378	−1·821
10	„	Bed rock at Sānichri H. S.	70·3	+263·197	1905-07	+261·330	−1·867
11	„	Stone embedded, Banmor Railway Station.	62·2	+ 60·127	1905-07	+ 58·306	−1·821
12	„	Platform, Banmor Railway Station.	62·2	+ 65·422	1905-07	+ 63·641	−1·781
13	„	Railway bridge	62·9	+ 71·909	1905-07	+ 70·122	−1·787
14	„	Railway culvert	64·4	+ 82·051	1905-07	+ 80·250	−1·801
15	„	Railway „	65·5	+ 86·881	1905-07	+ 85·055	−1·826
16	„	Railway „	67·1	+ 92·710	1905-07	+ 91·652	−1·058*
17	„	Railway „	68·0	+ 94·901	1905-07	+ 93·629	−1·272*
18	„	Railway „	69·2	+101·354	1905-07	+ 99·514	−1·840
19	„	Railway bridge	69·9	+114·093	1905-07	+112·266	−1·827
20	„	Railway culvert	71·6	+120·808	1905-07	+119·025	−1·783
21	„	Railway „	72·1	+121·833	1905-07	+120·034	−1·799
22	„	Platform, Morār Railway Station.	72·5	+123·555	1905-07	+121·739	−1·816
23	„	Railway culvert	72·5	+121·252	1905 07	+119·579	−1·673*
24	„	Railway „	73·1	+130·771	1905-07	+128·951	−1·820
27	„	Platform, Gwalior Railway Station	74·1	+147·688	1905-07	+145·860	−1·828
28	„	Railway culvert... ...	74·8	+153·563	1905-07	+151·728	−1·835
31	„	Standard bench-mark, Gwalior	77·0	+184·601	1905-07	+182·778	−1·823
		Revision of line No. 65 (Lucknow-Cawnpore).					
96	63B	Standard bench-mark Lucknow	0·0	0·000	1909-10	0·000	0·000
97	„	Railway bridge, Lucknow	0·1	+6·847	1909-10	+6·857	+0·010
98	„	Road culvert, Lucknow	0·5	−24·931	1909-10	−24·932	−0·001
7	„	Sill, ChristChurch, Lucknow	1·3	−30·079	1868-69	−30·091	−0·012
99	„	Mile-stone, Lucknow	1·5	−27·310	1909-10	−27·334	−0·024
6	„	Platform Lucknow museum	2·7	−28·691	1867-69	−28·715	−0·024
8	„	Block-stone embedded, Lucknow	0·1	−9·870	1868-69	−9·868	+0·002
9	„	Platform, Lucknow Railway Station	1·8	+5·744	1868-69	+5·695	−0·049*
10	„	Paved Seat, Lucknow	3·6	+10·130	1868-69	+10·122	−0·008
28	„	Block-stone embedded, Cawnpore	49·2	+13·651	1868-69	+13·764	+0·113
70	„	Block-stone embedded, Mahārājpur	61·3	+6·307	1864-65	+6·485	+0·178
51	„	Block-stone embedded, Bara Sirohi	59·4	+30·016	1864-65	+30·229	+0·213

* Reconstructed.

Digitized by Google

TABLE IV.

List of G.T.S. Triangulation Stations connected by spirit-levelling, season 1915-16.

Name of station.	Height above mean-sea-level.			Difference Old—New.	Remarks.
	New spirit-levelling.	Old spirit-levelling.	Triangulation.		
	Feet.	Feet.	Feet.	Feet.	
Burāla T. S. of the Jogī-Tīlā Meridional Series	588·175	...	598·800	+10·625	⊙ on ground floor mark-stone connected.
Pindi T. S. " " " ..	597·086	...	602·330	+5·244	Ditto.
Dipulāna T. S. of the Sutlej Series...	602·727	...	602·200	−0·527	Ditto.
Bannanwāla T. S. " " ..	623·903	...	623·800	−0·103	Ditto.
Pipli T. S. of the Gurhagarh Meridional Series	671·012	...	670·600	−0·412	Ditto.
Gūkhāwāli T. S. " " ...	670·414	...	666·700	−3·714	Ditto.
Sisāha T. S. of the Rahun Meridional Series	708·162	...	706·000	−2·162	Ditto.
Dholpur H. S. of the Great Arc Meridional Series	937·944	938·011	...	+0·067	⊙ on upper mark-stone at base of protecting pillar.

Digitized by Google

MAGNETIC SURVEY

By E. C. J. Bond.

The present report on the work of the magnetic party in 1915-16 comprises:—

I.—An account of the work in the field and in recess quarters.

II.—A note on each of the observatories*.

III.—Tables of the mean values of the magnetic elements, dates of magnetic disturbances, and hourly means and diurnal inequality of the magnetic elements at observatories in 1915.

Personnel of No. 18 PARTY.

Provincial Officers.

Mr. E.C.J. Bond, in charge.
" R. P. Ray, B.A.
" N. R. Mazumdar.
" R. B. Mathur, B.A.

Upper Subordinate Service.

Mr. B.B. Shome.

Lower Subordinate Service.

3 Magnetic Observers.
14 Computers, etc.

I.—Work in the Field and in Recess.

1. *Work during the field season.*—The first general magnetic survey was practically completed after the 73 permanently marked repeat stations were observed at in the previous season, and as these repeat stations will be visited for magnetic observations at intervals of 5 years, for the determination of secular change, no field observations were taken during the year 1915-16. It was necessary, however, for a detachment to proceed to Delhi to select a suitable site for a new repeat station as the "Bēla" land, on which the old station was situated, was being dug up under a scheme for grading the bank of the Jumna river. Comparative observations were taken by two observers at both the old and new sites, before the former was destroyed, to ensure a continuity of record for the determination of reliable secular change values for the locality.

The observatories at Dehra Dūn, Kodaikānal and Toungoo were inspected by the officer in charge during two months of the field season and a complete set of observations at each was taken by him for the yearly comparison of instruments. The Alibāg observatory which is independent of the magnetic survey of India was also visited for comparative observations.

The staff of the party was chiefly employed during the field season in the final reduction of the Declination and Horizontal Force at all field stations in India, Burma and Ceylon to the selected epoch, 1st January 1909.

At the request of the Port Commissioners of Rangoon for a survey officer to put the transit instrument at the Rangoon observatory into proper adjustment, the officer in charge of the magnetic party was directed to visit Rangoon for the purpose where he broke journey on his way to Toungoo to render the necessary assistance.

2. *Work during recess.*—The computation of the comparative observations taken during the field season and the computation and tabulation of the Declination, Dip, Horizontal Force and Vertical Force for the 3 observatories (Dehra Dūn, Kodaikānal and Toungoo) for 1915 have been completed. The mean values of these elements for the year 1915 derived from measurements of traces of all available days, excluding those of great disturbances, are given in table A at the end of the report.

The values of m were formerly computed with the moment of inertia determined at the commencement of the survey, but as the moment of inertia of all magnets has been steadily decreasing and the necessary corrections for the change were thus becoming large by using the old value, the latest value has been adopted from the 1st January 1915.

Since it was decided that the Q term in the distribution coefficient $(1+\frac{P}{r^2}+\frac{Q}{r^4}\ \&c.)^{-1}$ is not negligible with the Indian Survey magnets and is to be taken into account in the final reduction of the Horizontal Force, the values of p and q as determined by the formula which

* *Vide* Index Map No. 16.

Digitized by Google

is given in page 5 of the Narrative Report for 1908-09 are now used for the distribution coefficient instead of the approximate expression $1 - \frac{P}{r^3}$ formerly used in the computation of $\frac{m}{H}$.

The values of the moment of inertia and the distribution coefficient, corrected as above, have been used to determine the values of the Horizontal Force given in table A at the end of this report; consequently the values in this table cannot be compared with the values published in previous years.

The final reduction of the observations in Horizontal Force at all repeat and field stations to the selected epoch is making good progress.

The revised base line values of the Horizontal Force magnetographs of the Dehra Dūn, Barrackpore, Kodaikānal and Toungoo observatories have been computed from the Horizontal Force as determined from the finally adjusted constants of the magnets of these observatories.

The corrected monthly mean values of Horizontal Force at the above observatories have been plotted on a chart from which the lines of uniform secular variation have been derived.

The recomputation of the values of the Horizontal Force at the repeat and field stations, necessitated by the revised values of magnetic moment and distribution coefficient of the field magnets, are nearing completion.

The reduction of the Declination observations at all the repeat and field stations to the selected epoch will very shortly be completed. Each field station with its survey number, Latitude and Longitude and value of Declination will be tabulated in the serial order in which they occur in each successive Degree Sheet, from the left hand top corner to the right hand bottom corner.

It is proposed to issue with these Declination values, tables of secular change, descriptions of all repeat and field stations and an isogonic chart. With the aid of the secular change tables and the chart the Declination at any place, at any year other than the selected epoch, may be obtained. It will be necessary, however, to revise and extend these tables from time to time, as additional data derived from future observations at repeat stations become available, as it is not possible to predict to what extent the secular change might vary a few years hence. It would appear, since the secular change has not altered more than a minute in the last 10 years, that no very large change is likely to occur in the next few years and the tables can be used for all practical purposes until they are revised in 1919-20 when observations will be taken again at repeat stations.

3. *Programme for 1916-17.*—During the ensuing field season work will be limited to comparisons of instruments at the observatories by the officer in charge of the party.

All the members of the party will be employed throughout the year on the reduction of the survey to the selected epoch.

II.—The Observatories in 1915-16.

A.—Dehra Dun Observatory.

1. The observatory was in charge of the magnetic observer Babu Shri Dhar up to the 22nd December 1915, when he was relieved by Babu Abdul Majid who was placed temporarily in charge until the return of Babu Shri Dhar from medical leave on the 22nd September 1916.

The Horizontal Force and Declination magnetographs have worked satisfactorily during the year. The Vertical Force instrument has behaved as well as could be expected of these instruments and it was not necessary therefore to replace it by another spare instrument as was intended last year. The burner of the lamp of this instrument was altered by the Mathematical Instrument Office, Calcutta, and the lamp now burns satisfactorily.

After repairs to the underground observatory, carried out in 1912, to prevent the repetition of inundations during the rainy season, the walls of the observatory withstood the test of the monsoons up to last year; but unfortunately during the heavy rain in August this year the observatory began to leak and in the course of a few days the water rose almost three feet in the passage round the room and flowed over the 1½-foot wall across the doorway. As it was feared that the instruments might be swamped and to avoid any risk of injury to them, the wall at the doorway was raised to a height of about 4 feet.

The boulder trench round the observatory is connected by a drain pipe to carry off the accumulation of any subsoil water in it, to a large open pit which had been designed for the purpose outside the observatory, and the passage round the room of the observatory is simi-

Digitized by Google

larly connected to carry off any water collected in it to a masonry well; but the undersoil water had percolated into the pit and well at the same time that it entered the observatory and the water in each was at the same level.

Coolies were employed, night and day for about a fortnight, in bailing water out of the passage, drawing it up by a *charsa* (large leather bowl-shaped bucket) from the well and pumping it up from the pit at the rate of 250, 1200 and 500 gallons per hour respectively; but in spite of this the water continued to remain at the same level for three days, after which it gradually decreased and the passage pit and well were finally drained.

The settling down of the water was due more likely to a natural subsidence of the subsoil water on the cessation of rain in the hills than to the effect of bailing and pumping.

The outer walls of the underground observatory have suffered much from the frequent pressure of the subsoil water which percolates through the walls and plaster. After the subsidence of the water it was noticed that the plastering in the passage on the north side of the room had bulged out and cracked for more than half the length of the wall and a leak was also discovered under the door sill at the entrance to the underground room.

Although precautions might be taken by freshly plastering the walls of the observatory there is still a fear of further inundations as the walls are already weakened by the constant penetration of water during the rains. The safety of the observatory and instruments during the rainy season is therefore a problem which will require careful attention at an early date.

2. *Mean values of the Declination and H. F. constants.*—The table below gives the mean monthly values of magnetic collimation, the distribution constants $P_{1\cdot2}$ and $P_{2\cdot3}$ as obtained directly from the deflection observations and the accepted values of p and q used in determining the values of the revised distribution factor. The values of m are also given, corrected for revised distribution and change in the moment of inertia. These revised values of m are used in the computations for 1915 and are derived from the vibration observations as determined with the chronograph.

Mean values of the Constants of Magnet No. 17 in 1915.

Months.	Declination Constants.	H. F. Constants.						Remarks.
		Distribution Factors				Mean value of m		
	Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values p	Accepted values q	Monthly means.	Accepted m	
	′ ″							
January ...	−6 11	6·06	6·93					
February ...	−6 8	6·05	6·84			809·73	809 71	To April 20th.
March ..	−6 4	5·98	6·94					
April ...	−6 9	5·97	7·04					
May ...	−6 5	6 04	6·89					
June ...	−6 5	6·03	6·97					
July ...	−6 6	5 99	6·73	7·30	−382	809·40	809·46	From April 23rd to December 7t .
August ...	−6 3	6·01	6·74					
September ...	−6 3	6·04	6·89					
October ...	−6 1	6·01	6·87					
November ...	−6 10	5·91	6 78					
December ...	−6 11	...	...					To December 8th.
	−6 58	5·85	6·62			808 63	808·63	From December 9th

3. *Mean base line values.*— The table below gives the mean monthly observed and accepted values of the declination and horizontal force base lines: the accepted values have been used to compute the values of these elements for 1915. The H. F. base lines have been derived from H as determined with the present revised values of the moment of inertia and distribution coefficient.

Digitized by Google

Base line values of Magnetographs in 1915.

Months.	Declination.		Horizontal Force.		
	Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.	Remarks.
	° ′	° ′	C. G. S.	C. G. S.	
January ...	1 31·1		·32799	32799	
February ...	1 31·4		32799	·32799	
March ...	1 31·3		·32798	·32798	
April ...	1 31·2		·32795	·32795	
May ...	1 31·4		·32789	·32789	
June ...	1 31·2	1 31·2	·32787	·32787	
July	1 31·1		·32798	·32798	To H. M. 10 5 on 7th
			·32809	·32809	From 10 29 on 7th
August ...	1 31·2		·32805	·32805	
September	1 31·2		·32805	·32805	To September 14th
				·32802	For „ 15th
			·32798	·32798	From „ 16th
October ...	1 31·2		·32793	·32793	
November ...	1 30·8	1 30·8	·32790	·32790	
December ...	1 30·7	1 30·7	·32790	·32790	

4. *The mean scale values and temperature range.*— The mean scale values for 1915 for an ordinate of 1/25 inch are :— Horizontal Force 4·45 gammas.
Declination 1·03 minutes.
Vertical Force 4·84 to 6·29 gammas.

The mean temperature throughout the year was 27°·0 C. The temperature of reduction is 27°·0 C.

5. *Mean monthly values and secular change.*— The following table shows the monthly mean values of the magnetic elements for 1914-15 and the secular changes for that period : these secular changes are deduced from the values of H as corrected for the changes in the moment of inertia and the revised distribution coefficient.

Secular changes at Dehra Dūn in 1914-15.

Months.	Horizontal Force ·33000 C. G. S. +			Declination E. 2° +			Dip N. 44° +			Vertical Force ·32000 C. G. S. +		
	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	147	105	−42	20·3	17·1	−3·2	19·4	26·8	+7·4	373	471	+98
February ...	148	103	45	20·2	16·9	3·3	19·9	27·6	7·7	384	484	100
March ...	145	101	44	19·9	16·7	3·2	20·4	28·2	7·8	390	493	103
April ...	139	97	42	19·6	16·4	3·2	21·7	28·8	7·1	409	501	92
May ...	146	93	53	19·0	15·8	3·2	22·0	29·3	7·3	421	507	86
June ...	145	80	65	18·8	15·7	3·1	22·6	30·4	7·8	432	515	83
July ...	140	86	54	18·6	15·3	3·3	23·2	30·9	7·7	438	531	93
August ...	130	80	50	18·6	15·0	3·6	24·1	31·6	7·5	445	538	93
September ...	126	72	54	18·5	14·7	3·8	25·0	32·1	7·1	458	540	82
October ...	121	63	58	17·9	14·5	3·4	25·2	33·1	7·9	457	549	92
November ...	112	52	60	17·6	13·9	3·7	25·7	34·4	8·7	458	563	105
December ...	112	63	49	17·1	13·5	3·6	26·0	34·4	8·4	463	574	111
Means ...	134	83	−51	18·8	15·5	−3·3	22·9	30·6	+7·7	427	522	+95

Digitized by Google

B.—Barrackpore Observatory.

1. The observatory was closed on the 25th April 1915, but as the magnetic results at the observatory were given only up to the end of the year 1914 in last season's Records, it remains now to give them up to the time the observatory was closed.

2. *Mean values of the declination and H. F. constants.*—The following table gives the monthly mean values of the magnetic collimation, and the revised distribution constants and moment m, as explained in para 2 of the note on the Dehra Dun Observatory. These revised values of m were used in the computations for 1915.

Mean values of the constants of magnet No. 20 in 1915.

Months.	Declination constants.	H. F. constants.					
	Mean magnetic collimation.	Distribution factors.				Mean value of m.	
		$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.
	′ ″						
January	− 7 23	6·63	7·36	8·18	−301	936·65	935·66
February	− 7 29	6·71	7·32				
March	− 7 26	6·70	7·40				
April	− 7 28	6 75	7·47				

3. *Mean values of base lines.*—The table below gives the mean monthly observed and accepted base line values of the Declination and H. F. instruments: the accepted values have been used to compute the values of these elements for 1915. The H. F. base lines are derived from H as determined with the present revised values of the moment of inertia and distribution coefficients.

Base line values of Magnetographs in 1915.

Months.	Declination.		Horizontal Force.		Remarks.
	Mean value of base line.	Base line accepted.	Main value of base line.	Base line accepted.	
	° ′		C.G.S.	C.G.S.	
January	− 0 4·4	−0° 4′·5	·37097	·37096	
February	− 0 4·5		·37097	·37096	
March	− 0 4·6		37099	·37098	
April	− 0 4·5		·37105	·37100	From 1st to 6th.
				·37105	„ 7th to 18th.
				·37107	„ 19th to 26th.

4. *Mean scale values and temperature range.*—The mean scale values for the year for an ordinate of 1/25 inch are:—

Horizontal Force 4·86 gammas.
Declination 1·03 minutes.
Vertical Force 4·43 gammas.

The mean temperature for the 4 months, January to April, was 31°·7 C., with maximum and minimum values of 33°·1 C. to 31°·1 C. The temperature of reduction is 31°·0 C.

5. *Mean monthly values and secular changes.*—The following table gives the monthly mean values of the magnetic elements for 1914 and 1915 and the secular changes for that period: these secular change values are deduced from the values of H as corrected for the changes in the moment of inertia and the revised distribution coefficients.

Digitized by Google

Secular changes at Barrackpore in 1914-15.

Months.	Horizontal Force ·37000 C.G.S. +			Declination E. 0° +			Dip N. 30° +			Vertical Force ·22000 C.G.S. +		
	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.
	γ	γ	γ	′	′	′	′		′	γ	γ	γ
January ...	393	398	+5	34·6	29·0	−5·6	56·8	61·3	+4·5	421	489	+68
February ...	398	396	−2	34·1	28·6	5·5	57·2	61·7	4·5	430	496	66
March ...	396	398	+2	33·8	28·3	5·5	57·4	62·0	4·6	431	501	70
April ...	393	401	+8	33·4	27·7	5·7	58·0	62·2	4·2	438	506	68
May ...	408	...	...	32·8	...	...	58·1	...	...	449	...	...
June ...	415	...	...	32·4	...	...	58·7	...	...	462	...	...
July ...	403	...	..	32·0	...	...	59·1	...	...	461	...	...
August ...	399	...	...	31·5	...	...	59·6	...	...	466	...	...
September ...	397	...	...	31·1	...	...	60·2	...	...	473	...	...
October ...	399	...	...	30·7	...	...	60·3	...	...	476	...	...
November ...	401	...	...	30·2	...	...	61·0	...	...	488	...	...
December ...	406	...	...	29·6	...	...	60·8	...	...	488	...	...
Means ..	401	...	...	32·2	...	...	58·9	...	..	457	...	...

C.—Toungoo Observatory.

1. Mr. B. B. Shome held charge of the observatory up to the 26th January 1916 when he was relieved by Mr. K. N. Mukerji, formerly magnetic observer at the Barrackpore observatory. Mr. Shome was transferred to the head quarters office of the party at Dehra Dun.

The declination, H. F. and V. F. magnetographs have worked well throughout the year.

2. *Mean values of declination and H. F. constants.*—The table below gives the mean monthly values of magnetic collimation, and the revised distribution constants and moment m, as explained in para 2 of the note on the Dehra Dun observatory. These revised values of m were used in the computations for 1915.

The fall of the moment of the magnet continued to be 1·0 C.G.S. as in the previous year which is higher than the average normal fall of the other observatory magnets during a year.

Mean values of the Constants of Magnet No. 19A in 1915.

Months.	Declination constants.	H. F. constants.						Remarks.
	Mean magnetic collimation.	Distribution factors.				Mean values of m.		
		$P_{1.2}$	$P_{2.3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.	
January ...	−10′ 4″	8·29	9·02	10·19	−546	877·31	877·31	
February ...	−9 52	8·27	9·13			877·31	877·31	
						877·31	877·31	To March 13th.
March ...	−9 56	8·28	8·85			876·91	876·91	From 16th March.
April ...	−9 58	8·35	9·02			876·87	876·87	
May ...	−9 51	8·27	9·13			876·71	876·71	
June ...	−9 54	8·29	8·82			876·69	876·69	
July ...	−9 51	8·29	9·08			876·60	876·60	
August ...	−9 57	8·35	9·10			876·48	876·48	
September ...	−10 4	8·35	9·09			876·49	876·49	
October ...	−9 56	8·37	9·03			876·36	876·36	
November ...	−9 54	8·35	8·97			876·31	876·31	
December ...	−9 59	8·33	8·93			876·16	876·16	To December 9th.
						876·00	876·00	From December 11th

Digitized by Google

3. *Mean base line values.*—The following table gives the mean monthly observed and accepted base line values of the Declination and H F. magnetographs: the accepted values have been used to compute the values of these elements for 1915.

The H. F. base lines are derived from H as determined with the present revised values of the moment of inertia and distribution coefficients of magnet No. 19A and are not reduced as formerly to the value of magnet No. 19 which was in use in the earlier years of the observatory.

Base line values of Magnetographs in 1915.

Months.	Declination.		Horizontal force.		Months.	Declination.		Horizontal force.	
	Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.		Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.
	° ′		C. G. S.	C. G. S.		° ′	° ′	C. G. S.	C. G. S.
January .	0 51·2		·38633	·38633	July . .	0 52·3	0 52·3	·38627	·38627
February .	0 51·1	° ′	·38633	·38633	August .	0 52 8	0 52 8	·38624	·38624
March .	0 51·1	0 51·1	·38637 ·38623	·38630	September .	0 52 9	0 52·9	·38627	·38627
April .	0 51·1		·38626	·38626	October .	0 53 2	0 53 2	·38623	·38623
May .	0 51·7	0 51·7	·38631	·38631	November .	0 53·2	0 53·2	·38622	·38622
June . .	0 51·9	0 51·9	38631	·38631	December .	0 53·2	0 53 2	·38616	·38616

4. *Mean scale values and temperature range.*—The mean scale values for 1915 for an ordinate of 1/25 inch are:— Horizontal Force 5·39 gammas.

Declination 1·04 minutes.

Vertical Force 5·62 to 6·23 gammas.

The mean temperature for the year was 89°·2 Fahr. with maximum and minimum monthly values of 89°·7 Fahr. to 88°·9 Fahr. The temperature of reduction is 89°·0 Fahr.

5. *Mean monthly values and secular change.*—The table below gives the mean monthly values of the magnetic elements for 1914 and 1915 and the secular change for that period: these secular change values are deduced from the values of H as corrected for changes in the moment of inertia and the revised distribution coefficients. The values of H in this table are all in terms of magnet No. 19 A.

Secular changes at Toungoo in 1914-15.

Months.	Horizontal Force ·38000 C. G. S. +			Declination. 0° +			Dip N. 23° +			Vertical Force. 16000 C. G. S. +		
	1914.	1915.	Secular change.	1914. E.	1915. W.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January .	985	1000	+15	5·0	0·5	−5·5	5·7	6·7	+1·0	624	644	+20
February .	979	1003	24	4·4	1·0	5·4	5·8	6·8	1·0	623	647	24
March . .	981	1004	23	4·1	1·3	5·4	5·1	6·9	1·8	615	648	33
April . .	979	1002	23	3·6	1·6	5·2	6 0	7·0	1·0	626	648	22
May .	986	1009	23	3·2	2·1	5 3	5·9	6·8	0 9	628	649	21
June . .	985	1003	18	2 9	2·4	5·3	5·7	7·7	2 0	624	659	35
July . .	986	1005	19	2·5	3·0	5·5	5·8	7·2	1·4	626	653	27
August . .	980	1005	25	2·0	3·9	5·9	6·1	7·2	1·1	628	653	25
September .	982	1010	28	1·5	4·5	6·0	6·1	7·1	1·0	629	654	25
October . .	989	1006	17	1·1	5·1	6·2	6·7	7·6	0·9	640	659	19
November .	991	999	8	0·7	5·4	6·1	7·0	8·1	1·1	644	663	19
December .	997	1010	13	0·1	6·0	6·1	6·7	7·7	1 0	643	662	19
Means . .	985	1005	+20	2·6	3·1	−5·7	6·1	7·2	+1·1	629	653	+24

Digitized by Google

Secular changes at Barrackpore in 1914-15.

Months.	Horizontal Force ·37000 C.G.S. +			Declination E. 0° +			Dip N. 30° +			Vertical Force ·22000 C.G.S. +		
	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.
	γ	γ	γ	′	′	′	′		′	γ	γ	γ
January ...	393	398	+5	34·6	29·0	−5 6	56·8	61·3	+4·5	421	489	+68
February ...	398	396	−2	34·1	28·6	5 5	57·2	61·7	4·5	430	496	66
March ...	396	398	+2	33 8	28·3	5·5	57·4	62 0	4·6	431	501	70
April ...	393	401	+8	33·4	27·7	5 7	58 0	62·2	4·2	438	506	68
May ...	408	...	...	32·8	...	...	58·1	...	...	449	...	...
June ...	415	...	...	32·4	...	...	58·7	...	...	462	...	...
July ...	403	...	..	32·0	...	...	59·1	...	...	461	...	...
August ...	399	...	...	31·5	...	...	59 6	...	...	466	...	...
September ...	397	...	...	31·1	...	...	60·2	...	...	473	...	...
October ...	399	...	...	30·7	...	...	60·3	...	...	476	...	...
November ...	401	...	...	30·2	...	...	61·0	...	...	488	...	...
December ...	406	...	...	29·6	...	...	60·8	...	...	488	...	...
Means ..	401	...	...	32·2	...	...	58 9	...	..	457	...	...

C.—Toungoo Observatory.

1. Mr. B. B. Shome held charge of the observatory up to the 26th January 1916 when he was relieved by Mr. K. N. Mukerji, formerly magnetic observer at the Barrackpore observatory. Mr. Shome was transferred to the head quarters office of the party at Dehra Dun.

The declination, H. F. and V. F. magnetographs have worked well throughout the year.

2. *Mean values of declination and H. F. constants.*—The table below gives the mean monthly values of magnetic collimation, and the revised distribution constants and moment m, as explained in para 2 of the note on the Dehra Dun observatory. These revised values of m were used in the computations for 1915.

The fall of the moment of the magnet continued to be 1·0 C.G.S. as in the previous year which is higher than the average normal fall of the other observatory magnets during a year.

Mean values of the Constants of Magnet No. 19A in 1915.

Months.	Declination constants.	H. F. constants.						Remarks.
	Mean magnetic collimation.	Distribution factors.				Mean values of m.		
		$P_{1.2}$	$P_{2.3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.	
January ...	−10′ 4″	8 29	9·02	10·19	−546	877·31	877·31	
February ...	− 9 52	8·27	9·13			877 31	877·31	
						877·31	877·31	To March 13th.
March ...	− 9 56	8·28	8·85			876·91	876·91	From 16th March.
April ...	− 9 58	8·35	9 02			876·87	876·87	
May ...	− 9 51	8·27	9·13			876·71	876·71	
June ...	− 9 54	8·29	8·82			876·69	876·69	
July ...	− 9 51	8·29	9 08			876 60	876 60	
August ...	− 9 57	8·35	9·10			876 48	876 48	
September ...	−10 4	8·35	9 09			876·49	876 49	
October ...	− 9 56	8·37	9·03			876·36	876·36	
November ...	− 9 54	8·35	8 97			876·31	876·31	
December ...	− 9 59	8 33	8·93			876·16	876 16	To December 9th.
						876·00	876·00	From December 11th

Digitized by Google

3. *Mean base line values.*—The following table gives the mean monthly observed and accepted base line values of the Declination and H F. magnetographs: the accepted values have been used to compute the values of these elements for 1915.

The H. F. base lines are derived from H as determined with the present revised values of the moment of inertia and distribution coefficients of magnet No. 19A and are not reduced as formerly to the value of magnet No. 19 which was in use in the earlier years of the observatory.

Base line values of Magnetographs in 1915.

Months.	Declination.		Horizontal force.		Months.	Declination.		Horizontal force.	
	Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.		Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.
	° ′		C. G. S.	C. G. S.		° ′	° ′	C. G. S.	C. G. S.
January .	0 51·2	° ′ 0 51·1	·38633	·38633	July . .	0 52·3	0 52·3	·38627	·38627
February .	0 51·1		·38633	·38633	August .	0 52 8	0 52 8	·38624	·38624
March .	0 51·1		·38637 ·38623	·38630	September .	0 52 9	0 52·9	·38627	·38627
April .	0 51·1		·38626	·38626	October .	0 53 2	0 53 2	·38623	·38623
May .	0 51·7	0 51·7	·38631	·38631	November .	0 53·2	0 53·2	·38622	·38622
June . .	0 51·9	0 51·9	38631	·38631	December .	0 53·2	0 53 2	·38616	·38616

4. *Mean scale values and temperature range.*—The mean scale values for 1915 for an ordinate of 1/25 inch are:— Horizontal Force 5·39 gammas.

Declination 1·04 minutes.

Vertical Force 5·62 to 6·23 gammas.

The mean temperature for the year was 89°·2 Fahr. with maximum and minimum monthly values of 89°·7 Fahr. to 88°·9 Fahr. The temperature of reduction is 89°·0 Fahr.

5. *Mean monthly values and secular change.*—The table below gives the mean monthly values of the magnetic elements for 1914 and 1915 and the secular change for that period: these secular change values are deduced from the values of H as corrected for changes in the moment of inertia and the revised distribution coefficients. The values of H in this table are all in terms of magnet No. 19 A.

Secular changes at Toungoo in 1914-15.

Months.	Horizontal Force ·38000 C. G. S. +			Declination. 0° +			Dip N. 23° +			Vertical Force. 16000 C. G. S. +		
	1914.	1915.	Secular change.	1914. E.	1915. W.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January .	985	1000	+15	5·0	0·5	−5·5	5·7	6·7	+1·0	624	644	+20
February .	979	1003	24	4·4	1·0	5·4	5·8	6·8	1·0	623	647	24
March . .	981	1004	23	4·1	1·3	5·4	5·1	6·9	1·8	615	648	33
April . .	979	1002	23	3·6	1·6	5·2	6 0	7·0	1·0	626	648	22
May .	986	1009	23	3·2	2·1	5 3	5·9	6·8	0 9	628	649	21
June . .	985	1003	18	2 9	2·4	5·3	5·7	7·7	2 0	624	659	35
July . .	986	1005	19	2·5	3·0	5·5	5·8	7·2	1·4	626	653	27
August . .	980	1005	25	2·0	3 9	5·9	6·1	7·2	1·1	628	653	25
September .	982	1010	28	1·5	4·5	6·0	6·1	7·1	1·0	629	654	25
October . .	989	1006	17	1·1	5·1	6·2	6·7	7·6	0·9	640	659	19
November .	991	999	8	0·7	5·4	6·1	7·0	8·1	1·1	644	663	19
December .	997	1010	13	0·1	6·0	6·1	6·7	7·7	1 0	643	662	19
Means . .	985	1005	+20	2·6	3·1	−5·7	6·1	7·2	+1·1	629	653	+24

Digitized by Google

D.—Kodaikanal Observatory.

1. Magnetic observer Ramasvami Ayyangar held charge of the observatory during the year.

Thanks are due to the Director of the Solar Physics Observatory for the cordial assistance in all matters connected with the magnetic work.

The magnetographs worked satisfactorily throughout the year. The chuck of the magnet used with the observatory magnetometer had become worn and lost its grip: the spare chuck of another magnet was substituted on 25th January until the original chuck was repaired and used a month later. The temporary chuck was heavier and it was necessary to take a moment of inertia experiment with it as well as with the original chuck after repair, so as to preserve a continuity of record. No change in the moment of inertia was appreciable in the magnet when the repaired chuck was used.

During the inspection of the observatory the torsion head of the Declination magnetograph was turned on account of the gradual shift of the trace due to secular change.

2. *Mean values of Declination and H. F. constants.*—The table below gives the mean monthly values of the magnetic collimation, and the revised distribution constants and moment m, as explained in para. 2 of the note on the Dehra Dūn Observatory. These revised values of m were used in the computations for 1915 and are derived from the vibration observations as determined with the chronograph.

Mean values of the constants of magnet No. 16 in 1915.

Months.	Declination constants.	H. F. constants.						Months.	Declination constants.	H. F. constants.					
		Distribution Factors.				Mean values of m.				Distribution Factors.				Mean values of m.	
				Accepted values.								Accepted values.			
	Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	p	q	Monthly means.	Accepted m.		Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	p	q	Monthly means.	Accepted m.
January .	−3′ 27″	5·88	8·54	11·39	−1621	882·30	882·77	July .	−3′ 28″	5·86	8·72	11·39	−1621	882·49	882·77
February	−3 30	5·96	8 68			882 41		August .	−3 26	5·79	8·79			882·47	
March .	−3 28	6·00	8·55			882·47		September	−3 26	5·80	8·53			882·51	
April .	−3 29	5·93	8·65			882·42		October .	−3 27	5·78	8·80			882·60	
May .	−3 28	5·90	8·50			882·29		November	−3 20	5·81	8·68			882·78	
June .	−3 25	5·89	8·81			882 53		December	−3 21	5·69	8·86			882·78	

3. *Mean base line values.*—The following table gives the mean monthly observed and accepted base line values of the H. F. and Declination magnetographs: the accepted values have been used to compute the values of these elements for 1915. The H. F. base line values have been derived from H as determined with the present revised values of the moment of inertia and distribution coefficients.

Base line values of Magnetographs in 1915.

Months.	Declination.		Horizontal Force.		Months.	Declination.		Horizontal Force.	
	Mean value of Base line.	Base line accepted	Mean value of Base line.	Base line accepted.		Mean value of Base line.	Base line accepted	Mean value of Base line.	Base line accepted.
	° ′		C. G. S.	C. G. S.		° ′		C. G. S.	C. G. S.
January .	1 57·7	1° 57′·5	·37371	·37371	July .	1 57·3	1° 57′·5	·37370	·37370
February .	1 57·6		·37368	·37368	August .	1 57·5		·37371	·37371
March .	1 57 4		·37369	·37369	September .	1 57·7		·37370	·37370
April .	1 57 7		·37372	·37372	October .	1 57·4		·37370	·37370
May .	1 57·6		·37373	·37373	November .	1 57·7		·37367	·37367
June .	1 57·4		·37373	·37373	December .	1 57 4		·37363	·37363

Digitized by Google

4. *Mean scale values and temperature range.*—The mean scale values for 1915 for an ordinate of 1/25 inch are:—

Horizontal Force	5·90 gammas.
Declination	1·03 minutes.
Vertical Force	5·18 to 5·58 gammas.

The mean temperature for the year was 18°·5 C with maximum and minimum monthly values of 19°·0 C to 17°·5 C. The temperature of reduction is 19°·0 C.

5. *Mean monthly values and secular change.*— The table below gives the mean monthly values of the magnetic elements for 1914 and 1915 and the secular changes for that period: the secular change values are deduced from the values of H as corrected for the changes in the moment of inertia and the revised distribution coefficients.

Secular changes at Kodaikānal in 1914-15.

Months.	Horizontal Force ·37000 C. G. S. +			Declination W. 1° +			Dip N. 4° +			Vertical Force ·02000 C. G. S. +		
	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.	1914.	1915.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	599	608	+ 9	14·5	19·8	+ 5·3	8 2	13·7	+ 5·5	719	781	+ 62
February ...	606	606	0	14·9	20·3	5·4	8·5	15·0	6·5	723	794	71
March ...	605	611	6	15·2	20·6	5·4	9·1	15·8	6·7	730	804	74
April ...	604	617	13	15·7	21·0	5·3	9·8	15·9	6·1	737	805	68
May ...	608	618	10	16·3	21·6	5·3	10·5	16·7	6·2	745	814	69
June ...	602	610	8	16·7	22·2	5·5	11·7	17·2	5·5	758	818	60
July ...	602	610	8	17·1	22·6	5·5	12·0	17·9	5·9	761	827	66
August ...	600	619	19	17·5	23·0	5·5	12·5	17·2	4·7	767	820	53
September ...	607	623	16	18·3	23·4	5·1	12·5	17·9	5·4	767	827	60
October ...	605	620	15	19·3	23·8	4 5	12·7	18·1	5·4	769	829	60
November ..	602	609	7	19·8	24·2	4·4	13·7	19·2	5·5	780	841	61
December ...	610	620	10	20·2	25·0	4·8	13·5	19·1	5·6	778	841	63
Means ...	604	614	+ 10	17·1	22·3	+ 5·2	11·2	17·0	+ 5·8	753	817	+ 64

6. *Transfer of the Kodaikānal Observatory.*—It has been deemed advisable to place the Kodaikānal Observatory under the control of the Meteorological Department, for a better supervision of the work of the observatory than is possible at so great a distance from the Survey Head Quarters at Dehra Dun. With the approval of the Director General of Observatories and the sanction of the Government of India, the magnetic observatory and the observatory staff were transferred to the Meteorological Department on the 1st August 1916.

It has been arranged that the Director of the Kodaikānal Observatory will continue to send the periodical returns of the magnetic observations as usual, in original and duplicate, to the Officer in charge of No. 18 Party for the computation of the observations and for record.

III.—Tables of Results.

A—*Mean values of the magnetic elements at observatories in 1915.*

Observatory.	Latitude and Longitude.	Dip.	Declination.	H. F.	V. F.
	° ′ ″	° ′	° ′	C. G. S.	C. G. S.
Dehra Dūn ...	30 19 19 N 78 3 19 E	N. 44 30·6	E. 2 15·5	·33083	·32522
Toungoo ...	18 55 45 N 96 27 3 E	N. 23 7·2	W. 0 3·1	·39005	·16653
Kodaikānal ...	10 13 50 N 77 27 46 E	N. 4 17·0	W. 1 22·3	·37614	·02817

Digitized by Google

D = Dehra Dûn ... { Lat. 30° 19′ 19″ N. Long. 78 3 19 E.

B = Barrackpore ... { Lat. 22 46 29 N. Long. 88 21 39 E.

T = Toungoo ... { Lat. 18 55 45 N. Long. 96 27 3 E.

K = Kodaikānal ... { Lat. 10 13 50 N. Long. 77 27 46 E.

B.— *Dates of Magnetic disturbances in 1915.*

Dates.	January.				February.				March.				April.				May.			June.			July.			August.			September.			October.			November.			December.		
	D	B	T	K	D	B	T	K	D	B	T	K	D	B	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K
1 ...	S	S	S	S	C	C	C	C	C	C	C	C	S	S	S	S	S	S	S	C	C	C	C	C	C	S	S	S	C	C	C	S	S	S	G	G	G	C	C	C
2 ...	C	C	C	C	S	S	S	S	C	C	C	C	S	S	S	S	S	S	M	C	C	C	S	S	S	S	S	S	C	C	C	C	C	C	M	M	M	C	C	C
3 ...	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S	S	S	S	S	C	—	C	S	S	S	S	S	S	C	C	C	C	C	C	C	C	C	C	C	C
4 ...	S	S	S	S	S	S	S	S	C	C	C	C	C	C	—	C	S	S	S	C	C	C	C	C	C	S	S	S	C	C	C	C	C	C	C	C	C	C	C	C
5 ...	S	S	S	S	S	S	S	S	C	S	S	S	C	C	C	C	S	S	S	C	C	C	C	C	C	C	C	C	S	S	C	C	C	C	S	S	S	C	C	C
6 ...	S	S	S	S	S	S	S	S	S	S	S	S	S	C	S	S	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C	C	C	C	S	S	S	M	M	M
7 ...	S	S	S	S	C	C	C	C	S	S	S	S	S	C	S	C	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	S	S	S	S	S	S
8 ...	S	S	S	S	S	S	S	S	S	S	S	S	G	G	G	G	C	C	C	S	S	S	S	S	S	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C
9 ...	C	C	C	C	S	S	S	S	S	S	S	S	M	S	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
10 ...	C	C	C	C	C	C	C	S	S	S	S	S	C	C	C	C	C	C	S	C	C	C	S	S	S	C	C	C	C	C	C	S	S	S	S	S	S	S	C	C
11 ...	C	C	C	C	C	C	C	C	S	S	S	S	C	C	C	C	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C
12 ...	C	C	C	C	S	S	S	S	S	S	S	S	C	C	C	C	S	S	C	S	S	S	C	C	C	C	C	C	S	S	C	C	C	C	C	C	C	C	C	C
13 ...	S	S	S	S	S	S	S	S	S	C	C	S	C	C	—	C	S	C	C	S	S	S	C	C	C	C	C	C	C	C	C	M	M	M	C	C	C	S	S	S
14 ...	S	S	S	S	C	C	C	C	C	C	C	C	C	C	—	C	S	S	S	C	C	S	C	C	C	C	C	C	C	C	C	G	G	G	C	C	C	S	S	S
15 ...	S	C	C	C	S	S	S	S	C	C	C	C	S	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C	S	S	S	G	G	G	G	M	M	S	S	S
16 ...	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S	S	S	S	S	V. G.	V. G.	V. G.	C	C	C	S	S	S	S	S	S	M	M	S	M	M	M	C	C	C
17 ...	C	C	C	C	C	C	C	C	S	S	S	S	C	C	S	S	C	C	C	G	G	G	C	C	C	S	S	S	C	C	C	C	G	C	M	M	M	C	C	C
18 ...	C	C	C	C	C	C	C	C	S	S	S	S	S	S	S	S	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C	G	G	G	S	S	S	C	C	C
19 ...	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C	S	S	S	C	C	C	G	G	G	S	S	S	S	S	S
20 ...	S	S	S	S	S	S	S	S	M	M	M	M	S	S	S	S	S	S	S	S	S	S	C	C	C	S	S	S	S	S	C	S	C	S	S	S	S	C	C	C
21 ..	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	C	S	S	S	S	S	S	S	S	S	S	C	C	M	M	S	S	S	S	S	S	S	C	C	C
22 ...	S	S	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	S	C	C	M	M	S	G	S	G	C	C	C	S	S	S
23 ...	C	C	C	C	S	S	S	S	S	S	S	S	M	S	S	C	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S	M	M	M	C	C	C	S	S	S
24 ...	C	C	C	C	S	S	S	S	C	C	C	C	C	C	C	C	S	S	S	S	S	S	C	C	S	S	S	S	S	S	S	M	M	M	S	S	C	S	S	S
25 ...	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
26 ...	S	S	S	S	S	S	S	S	S	S	S	S	S	—	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	C	C	S	S	S	S	S	S
27 ...	S	S	S	S	C	C	C	C	S	C	C	C	S	—	S	S	M	M	S	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	S	S	S	C	C	C
28 ...	S	S	—	S	C	C	C	C	C	C	C	C	C	—	C	C	M	M	S	S	C	S	C	C	C	S	S	S	S	S	S	C	C	C	C	C	C	C	C	C
29 ...	C	C	C	C	...	...	...	..	C	C	C	C	C	—	C	C	C	C	C	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C
30 ...	S	S	S	S	...	...	...	...	S	S	—	S	S	—	S	S	C	C	C	C	C	C	S	S	S	C	C	C	...	...	...	S	S	S	...	...	...	C	C	C
31 ...	C	C	C	C	...	...	...	...	C	C	C	C	...	...	...	...	S	S	C	...	...	...	C	C	C	C	C	C	...	...	...	S	S	S	...	...	...	...	...	...
C ...	14	15	15	15	11	11	11	10	11	13	13	12	13	13	10	15	14	14	14	14	14	13	18	19	18	11	12	12	15	15	18	12	13	13	9	10	11	16	17	17
S ...	17	16	15	16	17	17	17	18	19	17	16	18	14	11	16	14	15	15	16	14	13	15	13	12	13	20	19	19	13	13	12	10	9	10	15	14	13	13	12	12
M ...	...	...	...	...	...	...	...	...	1	1	...	1	2	...	...	...	2	2	1	...	...	...	...	...	...	...	...	...	2	2	...	4	4	3	3	4	4	1	1	1
G ...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	1	1	...	...	...	1	1	1	...	...	...	...	...	...	...	...	...	5	5	5	3	2	2	1	1	1
V.G. ...	...	...	...	...	...	...	...	...	...	...	...	...		...	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Trace lost ...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	3	...	...	...	...	...	1	...	..	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...

C = Calm. S = Slight. M = Moderate. G = Great. V. G. = Very Great. — = Trace lost.

Digitized by Google

C.—*Hourly Means of the Declination at Dehra Dun in 1915, determined from all available days. Declination = E. 2° + tabular quantity.*

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	17′·4	17′·3	17′·2	17′·0	16′·9	16′·7	16′·5	16′·6	17′·4	18′·0	17′·6	16′·7	16′·1	16′·4	16′·9	17′·4	17′·6	17′·4	17′·2	17′·4	17′·3	17′·3	17′·5	17′·4	17′·3	17′·1
Feb.	17·3	17·2	17·1	17·0	17·0	16·8	16·8	17·1	17·5	17·3	16·7	15·8	15·4	15·5	16·1	17·1	17·6	17·3	16·9	16·9	17·0	17·0	17·3	17·3	17·3	16·9
Mar.	16·9	17·0	16·8	16·6	16·6	16·6	16·6	17·4	18·7	19·3	18·6	16·9	15·2	14·2	14·3	15·4	16·4	16·9	16·7	16·5	16·5	16·7	16·9	17·0	16·9	16·7
Oct.	14·8	14·8	14·7	14·8	14·6	14·4	14·3	15·2	16·2	16·1	15·1	13·8	12·6	12·3	13·0	14·0	14·6	14·6	14·4	14·5	14·5	14·6	14·8	14·8	14·8	14·5
Nov.	14·4	14·2	14·3	14·1	13·7	13·7	13·7	14·1	14·5	14·3	13·5	12·5	12·3	12·9	13·7	14·4	14·4	14·3	14·3	14·2	14·0	14·0	14·1	14·2	14·2	13·9
Dec	13·8	13·5	13·5	13·4	13·2	13·2	13·2	13·3	14·0	14·3	13·9	12·7	12·4	12·6	13·2	13·7	13·8	13·7	13·8	13·7	13·6	13·6	13·5	13·7	13·6	13·5
Means	15·8	15·7	15·6	15·5	15·3	15·2	15·2	15·6	16·4	16·6	15·9	14·7	14·0	14·0	14·5	15·3	15·7	15·7	15·6	15·5	15·5	15·5	15·7	15·7	15·7	15·4
Summer. April	16·9	16·9	16·9	16·8	16·8	16·7	17·1	18·2	19·2	19·4	18·0	15·6	13·7	12·9	13·4	14·7	15·7	16·2	16·1	16·0	16·0	16·3	16·6	16·8	16·9	16·4
May	16·3	16·5	16·4	16·5	16·3	16·6	17·7	18·6	18·7	17·8	15·9	14·0	12·9	12·7	13·4	14·4	15·2	15·7	15·9	15·6	15·6	15·7	15·9	16·0	16·3	15·8
June	15·9	16·1	16·2	16·3	16·2	16·5	17·8	18·7	18·9	18·0	16·3	14·5	13·1	12·5	12·5	13·2	14·2	15·2	15·7	15·6	15·4	15·4	15·7	15·8	15·9	15·7
July	15·5	15·7	15·7	15·8	15·8	16·2	17·8	19·0	18·9	17·9	16·0	13·8	12·3	11·9	12·1	12·9	13·9	14·9	15·5	15·3	15·0	15·0	15·3	15·3	15·5	15·3
Aug.	15·2	15·2	15·4	15·5	15·6	15·9	17·2	18·3	18·5	17·1	15·1	13·1	12·0	11·7	12·0	13·1	14·1	14·9	15·4	15·0	14·9	14·8	15·0	15·0	15·2	15·0
Sep.	14·9	15·0	15·1	15·0	15·1	15·4	16·2	17·5	17·9	16·7	14·6	12·8	11·7	11·2	11·8	13·3	14·4	14·9	14·9	14·6	14·6	14·7	14·8	14·8	14·9	14·7
Means	15·8	15·9	16·0	16·0	16·0	16·2	17·3	18·4	18·7	17·8	16·0	14·0	12·6	12·2	12·5	13·6	14·6	15·3	15·6	15·4	15·3	15·3	15·6	15·6	15·8	15·5

Diurnal Inequality of the Declination at Dehra Dun in 1915, deduced from the above Table.

Winter. Jan.	+0′·3	+0′·2	+0′·1	−0′·1	−0′·2	−0′·4	−0′·6	−0′·5	+0′·3	+0′·9	+0′·5	−0′·4	−1′·0	−0′·7	−0′·2	+0′·3	+0′·5	+0′·3	+0′·1	+0′·3	+0′·2	+0′·2	+0′·4	+0′·3	+0′·2	
Feb.	+0·4	+0·3	+0·2	+0·1	+0·1	−0·1	−0·1	+0·2	+0·6	+0·4	−0·2	−1·1	−1·5	−1·4	−0·8	+0·2	+0·7	+0·4	0	0	+0·1	+0·1	+0·4	+0·4	+0·4	
Mar.	+0·2	+0·3	+0·1	−0·1	−0·1	−0·1	−0·1	+0·7	+2·0	+2·6	+1·9	+0·2	−1·5	−2·5	−2·4	−1·3	−0·3	+0·2	0	−0·2	−0·2	0	+0·2	+0·3	+0·2	
Oct.	+0·3	+0·3	+0·2	+0·3	+0·1	−0·1	−0·2	+0·7	+1·7	+1·6	+0·6	−0·7	−1·9	−2·2	−1·5	−0·5	+0·1	+0·1	−0·1	0	0	+0·1	+0·3	+0·3	+0·3	
Nov.	+0·5	+0·3	+0·4	+0·2	−0·2	−0·2	−0·2	+0·2	+0·6	+0·4	−0·4	−1·4	−1·6	−1·0	−0·2	+0·5	+0·5	+0·4	+0·4	+0·3	+0·1	+0·1	+0·2	+0·3	+0·3	
Dec.	+0·3	0	0	−0·1	−0·3	−0·3	−0·3	−0·2	+0·5	+0·8	+0·4	−0·8	−1·1	−0·9	−0·3	+0·2	+0·3	+0·2	+0·3	+0·2	+0·1	+0·1	0	+0·2	+0·1	
Means	+0·4	+0·3	+0·2	+0·1	−0·1	−0·2	−0·2	+0·2	+1·0	+1·2	+0·5	−0·7	−1·4	−1·4	−0·9	−0·1	+0·3	+0·3	+0·2	+0·1	+0·1	+0·1	+0·3	+0·3	+0·3	
Summer. April	+0·5	+0·5	+0·5	+0·4	+0·4	+0·3	+0·7	+1·8	+2·8	+3·0	+1·6	−0·8	−2·7	−3·5	−3·0	−1·7	−0·7	−0·2	−0·3	−0·4	−0·4	−0·1	+0·2	+0·4	+0·5	
May	+0·5	+0·7	+0·6	+0·7	+0·5	+0·8	+1·9	+2·8	+2·9	+2·0	+0·1	−1·8	−2·9	−3·1	−2·4	−1·4	−0·6	−0·1	+0·1	−0·2	−0·2	−0·1	+0·1	+0·2	+0·5	
June	+0·2	+0·4	+0·5	+0·6	+0·5	+0·8	+2·1	+3·0	+3·2	+2·3	+0·6	−1·2	−2·6	−3·2	−3·2	−2·5	−1·5	−0·5	0	−0·1	−0·3	−0·3	0	+0·1	+0·2	
July	+0·2	+0·4	+0·4	+0·5	+0·5	+0·9	+2·5	+3·7	+3·6	+2·6	+0·7	−1·5	−3·0	−3·4	−3·2	−2·4	−1·4	−0·4	+0·2	0	−0·3	−0·3	0	0	+0·2	
Aug.	+0·2	+0·2	+0·4	+0·5	+0·6	+0·9	+2·2	+3·3	+3·5	+2·1	+0·1	−1·9	−3·0	−3·3	−3·0	−1·9	−0·9	−0·1	+0·4	0	−0·1	−0·2	0	+0·1	+0·2	
Sep.	+0·2	+0·3	+0·4	+0·3	+0·4	+0·7	+1·5	+2·8	+3·2	+2·0	−0·1	−1·9	−3·0	−3·5	−2·9	−1·4	−0·3	+0·2	+0·2	−0·1	−0·1	0	+0·1	+0·1	+0·2	
Means	+0·3	+0·4	+0·5	+0·5	+0·5	+0·7	+1·8	+2·9	+3·2	+2·3	+0·5	−1·5	−2·9	−3·3	−3·0	−1·9	−0·9	−0·2	+0·1	−0·1	−0·2	−0·2	+0·1	+0·1	+0·3	

NOTE:—When the sign is + the magnet points to the East, and when − to the West of the mean position.

Digitized by Google

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Dehra Dun in 1915, from all available days. Horizontal Force = ·33000 C.G.S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter. Jan.	103	103	103	104	104	106	107	110	111	109	103	108	115	114	110	108	104	101	100	101	101	100	101	101	103	105
Winter. Feb.	99	98	101	101	100	102	103	103	101	102	105	114	117	118	117	110	105	99	97	96	97	96	100	97	99	103
Winter. Mar.	100	98	100	102	100	100	101	100	98	99	105	108	108	111	111	108	101	96	92	94	95	95	97	94	99	101
Winter. Oct.	63	60	63	62	62	63	64	61	57	57	62	67	74	79	77	69	64	60	56	56	56	55	57	60	64	63
Winter. Nov.	46	50	51	50	52	51	52	51	50	52	55	60	61	60	58	52	48	49	49	49	48	50	52	52	52	52
Winter. Dec.	59	60	60	62	63	63	64	65	65	62	60	65	66	65	67	67	65	63	61	60	59	59	62	61	62	63
Means	78	78	80	80	80	81	82	82	80	80	82	87	90	91	90	86	81	78	76	76	76	76	78	78	80	81
Summer. April	91	94	94	93	94	96	96	93	90	91	99	105	111	115	114	109	102	95	91	89	90	91	92	91	92	97
Summer. May	91	88	91	90	93	92	92	88	85	87	95	104	109	111	107	103	97	91	87	86	87	88	90	89	90	93
Summer. June	77	78	77	78	78	79	80	79	74	74	79	84	93	96	96	91	82	75	70	71	73	74	76	77	79	80
Summer. July	81	82	81	82	82	84	84	83	80	83	89	94	100	104	103	99	91	84	77	77	78	80	81	82	82	86
Summer. Aug.	78	81	80	79	79	79	80	76	70	72	79	86	94	94	92	85	81	76	74	73	73	76	76	77	78	80
Summer. Sep.	75	75	77	77	77	76	75	69	60	59	63	69	76	86	86	81	75	68	66	67	67	67	69	72	74	72
Means	82	83	83	83	84	84	85	81	77	78	84	90	97	101	100	95	88	82	78	77	78	79	81	81	83	85

Diurnal Inequality of the Horizontal Force at Dehra Dun in 1915, deduced from the above Table.

	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter. Jan.	− 2	− 2	− 2	− 1	− 1	+ 1	+ 2	+ 5	+ 6	+ 4	− 2	+ 3	+ 10	+ 9	+ 5	+ 3	− 1	− 4	− 5	− 4	− 4	− 5	− 4	− 4	− 2	
Winter. Feb.	− 4	− 5	− 2	− 2	− 3	− 1	0	0	− 2	− 1	+ 2	+ 11	+ 14	+ 15	+ 14	+ 7	+ 2	− 4	− 6	− 7	− 6	− 7	− 3	− 6	− 4	
Winter. Mar.	− 1	− 3	− 1	+ 1	− 1	− 1	0	− 1	− 3	− 2	+ 4	+ 7	+ 7	+ 10	+ 10	+ 7	0	− 5	− 9	− 7	− 6	− 6	− 4	− 7	− 2	
Winter. Oct.	− 0	− 3	0	− 1	− 1	0	+ 1	− 2	− 6	− 6	− 1	+ 4	+ 11	+ 16	+ 14	+ 6	+ 1	− 3	− 7	− 7	− 7	− 8	− 6	− 3	+ 1	
Winter. Nov.	− 6	− 2	− 1	− 2	0	− 1	0	− 1	− 2	0	+ 3	+ 8	+ 9	+ 8	+ 6	0	− 4	− 3	− 3	− 3	− 4	− 2	0	0	0	
Winter. Dec.	− 4	− 3	− 3	− 1	0	0	+ 1	+ 2	+ 2	− 1	− 3	+ 2	+ 3	+ 2	+ 4	+ 4	+ 2	0	− 2	− 3	− 4	− 4	− 1	− 2	− 1	
Means	− 3	− 3	− 1	− 1	− 1	0	+ 1	+ 1	− 1	− 1	+ 1	+ 6	+ 9	+ 10	+ 9	+ 5	0	− 3	− 5	− 5	− 5	− 5	− 3	− 3	− 1	
Summer. April	− 6	− 3	− 3	− 4	− 3	− 1	− 1	− 4	− 7	− 6	+ 2	+ 8	+ 14	+ 18	+ 17	+ 12	+ 5	− 2	− 6	− 8	− 7	− 6	− 5	− 6	− 5	
Summer. May	− 2	− 5	− 2	− 3	0	− 1	− 1	− 5	− 8	− 6	+ 2	+ 11	+ 16	+ 18	+ 14	+ 10	+ 4	− 2	− 6	− 7	− 6	− 5	− 3	− 4	− 3	
Summer. June	− 3	− 2	− 3	− 2	− 2	− 1	0	− 1	− 6	− 6	− 1	+ 4	+ 13	+ 16	+ 16	+ 11	+ 2	− 5	− 10	− 9	− 7	− 6	− 4	− 3	− 1	
Summer. July	− 5	− 4	− 5	− 4	− 4	− 2	− 2	− 3	− 6	− 3	+ 3	+ 8	+ 14	+ 18	+ 17	+ 13	+ 5	− 2	− 9	− 9	− 8	− 6	− 5	− 4	− 4	
Summer. Aug.	− 2	+ 1	0	− 1	− 1	− 1	0	− 4	− 10	− 8	− 1	+ 6	+ 14	+ 14	+ 12	+ 5	+ 1	− 4	− 6	− 7	− 7	− 4	− 4	− 3	− 2	
Summer. Sep.	+ 3	+ 3	+ 5	+ 5	+ 5	+ 4	+ 3	− 3	− 12	− 13	− 9	− 3	+ 4	+ 14	+ 14	+ 9	+ 3	− 4	− 6	− 5	− 5	− 5	− 3	0	+ 2	
Means	− 3	− 2	− 2	− 2	− 1	− 1	0	− 4	− 8	− 7	− 1	+ 5	+ 12	+ 16	+ 15	+ 10	+ 3	− 3	− 7	− 8	− 7	− 6	− 4	− 4	− 2	

Note.—When the sign is + the H.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of Vertical Force in C.G.S. Units (corrected for temperature) at Dehra Dun in 1915, from all available days. Vertical Force = ·32000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	472	471	472	472	472	472	472	472	473	472	468	465	466	468	471	472	471	471	472	473	473	473	473	473	473	471
	Feb.	485	484	485	484	484	484	484	484	484	483	480	481	480	482	485	486	486	484	485	485	486	486	487	486	486	484
	Mar.	497	496	496	496	495	495	496	499	499	495	488	479	477	482	488	493	495	495	494	496	496	496	497	497	498	493
	Oct.	553	553	553	553	552	553	553	555	554	551	545	535	533	538	543	546	548	548	549	550	551	551	552	553	552	549
	Nov.	565	565	564	564	564	564	564	565	563	561	557	554	555	559	561	563	563	563	564	564	564	565	565	564	564	563
	Dec.	575	575	575	575	575	575	575	575	575	573	569	568	568	571	574	575	575	574	575	574	575	575	575	574	574	574
	Means	525	524	524	524	524	524	524	525	525	523	518	514	513	517	520	523	523	523	523	524	524	524	525	525	525	522
Summer.	April	504	505	504	504	504	505	506	508	508	502	493	484	485	490	496	501	503	503	502	503	505	506	506	506	506	501
	May	510	510	511	510	510	511	514	513	508	500	493	491	493	498	503	507	508	509	509	509	510	511	512	511	511	507
	June	519	520	519	519	519	521	524	523	516	509	502	497	499	502	507	511	516	517	518	519	519	520	521	521	521	515
	July	535	535	535	535	535	538	541	539	533	526	519	513	514	517	521	527	531	534	534	534	535	536	537	537	537	531
	Aug.	541	541	541	541	541	542	546	545	541	533	528	523	525	528	532	535	537	539	539	539	540	541	541	542	542	538
	Sep.	544	544	544	544	544	544	547	548	545	538	531	525	524	527	533	539	542	542	541	542	544	545	545	545	545	540
	Means	526	526	526	526	526	527	530	529	525	518	511	506	507	510	515	520	523	524	524	524	526	527	527	527	527	522

Diurnal Inequality of the Vertical Force at Dehra Dun in 1915, deduced from the above Table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	+ 1	0	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 2	+ 1	− 3	− 6	− 5	− 3	0	+ 1	0	0	+ 1	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	
	Feb.	+ 1	0	+ 1	0	0	0	0	0	0	− 1	− 4	− 3	− 4	− 2	+ 1	+ 2	+ 2	0	+ 1	+ 1	+ 2	+ 2	+ 3	+ 2	+ 2	
	Mar.	+ 4	+ 3	+ 3	+ 3	+ 2	+ 2	+ 3	+ 6	+ 6	+ 2	− 5	−14	−16	−11	− 5	0	+ 2	+ 2	+ 1	+ 3	+ 3	+ 3	+ 4	+ 4	+ 5	
	Oct.	+ 4	+ 4	+ 4	+ 4	+ 3	+ 4	+ 4	+ 6	+ 5	+ 2	− 4	−14	−16	−11	− 6	− 3	− 1	− 1	0	+ 1	+ 2	+ 2	+ 3	+ 4	+ 3	
	Nov.	+ 2	+ 2	+ 1	+ 1	+ 1	+ 1	+ 1	+ 2	0	− 2	− 6	− 9	− 8	− 4	− 2	0	0	0	+ 1	+ 1	+ 1	+ 2	+ 2	+ 1	+ 1	
	Dec.	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	− 1	− 5	− 6	− 6	− 3	0	+ 1	+ 1	0	+ 1	0	+ 1	+ 1	+ 1	0	0	
	Means	+ 3	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	+ 1	− 4	− 8	− 9	− 5	− 2	+ 1	+ 1	+ 1	+ 1	+ 2	+ 2	+ 2	+ 3	+ 3	+ 3	
Summer.	April	+ 3	+ 4	+ 3	+ 3	+ 3	+ 4	+ 5	+ 7	+ 7	+ 1	− 8	−17	−16	−11	− 5	0	+ 2	+ 2	+ 1	+ 2	+ 4	+ 5	+ 5	+ 5	+ 5	
	May	+ 3	+ 3	+ 4	+ 3	+ 3	+ 4	+ 7	+ 6	+ 1	− 7	−14	−16	−14	− 9	− 4	0	+ 1	+ 2	+ 2	+ 2	+ 3	+ 4	+ 5	+ 4	+ 4	
	June	+ 4	+ 5	+ 4	+ 4	+ 4	+ 6	+ 9	+ 8	+ 1	− 6	−13	−18	−16	−13	− 8	− 4	+ 1	+ 2	+ 3	+ 4	+ 4	+ 5	+ 6	+ 6	+ 6	
	July	+ 4	+ 4	+ 4	+ 4	+ 4	+ 7	+10	+ 8	+ 2	− 5	−12	−18	−17	−14	−10	− 4	0	+ 3	+ 3	+ 3	+ 4	+ 5	+ 6	+ 6	+ 6	
	Aug.	+ 3	+ 3	+ 3	+ 3	+ 3	+ 4	+ 8	+ 7	+ 3	− 5	−10	−15	−13	−10	− 6	− 3	− 1	+ 1	+ 1	+ 1	+ 2	+ 3	+ 3	+ 4	+ 4	
	Sep.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 7	+ 8	+ 5	− 2	− 9	−15	−16	−13	− 7	− 1	+ 2	+ 2	+ 1	+ 2	+ 4	+ 5	+ 5	+ 5	+ 5	
	Means	+ 4	+ 4	+ 4	+ 4	+ 4	+ 5	+ 8	+ 7	+ 3	− 4	−11	−16	−15	−12	− 7	− 2	+ 1	+ 2	+ 2	+ 2	+ 4	+ 5	+ 5	+ 5	+ 5	

NOTE.—When the sign is + the V.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of the Dip at Dehra Dun in 1915, determined from all available days. Dip = N. 44° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	26′·9	26′·9	26′·9	26′·9	26′·9	26′·8	26′·7	26′·6	26′·6	26′·6	26′·7	26′·3	26′·0	26′·2	26′·5	26′·7	26′·8	27′·0	27′·1	27′·1	37′·1	27′·1	27′·1	27′·1	27′·0	26′·8
Feb.	27·8	27·8	27·7	27·7	27·7	27·6	27·6	27·6	27·7	27·6	27·3	26·8	26·6	26·7	26·9	27·3	27·6	27·8	27·9	28·0	28·0	28·0	27·9	28·0	27·9	27·6
Mar.	28·4	28·5	28·3	28·3	28·3	28·3	28·3	28·5	28·6	28·4	27·7	27·0	27·0	27·0	27·4	27·8	28·3	28·5	28·7	28·7	28·6	28·6	28·5	28·7	28·5	28·2
Oct.	33·3	33·5	33·3	33·3	33·3	33·3	33·2	33·5	33·7	33·5	32·9	32·1	31·6	31·7	32·0	32·6	32·9	33·2	33·5	33·5	33·5	33·6	33·6	33·5	33·2	33·1
Nov.	34·8	34·6	34·5	34·6	34·4	34·5	34·4	34·6	34·5	34·3	33·9	33·5	33·5	33·8	34·0	34·4	34·6	34·5	34·6	34·6	34·6	34·6	34·5	34·4	34·4	34·4
Dec.	34·6	34·6	34·6	34·5	34·4	34·4	34·4	34·3	34·3	34·4	34·3	34·0	33·9	34·1	34·2	34·2	34·3	34·4	34·5	34·6	34·6	34·6	34·5	34·5	34·4	34·4
Means	31·0	31·0	30·9	30·9	30·8	30·8	30·8	30·9	30·9	30·8	30·5	30·0	29·8	29·9	30·2	30·5	30·8	30·9	31·1	31·1	31·1	31·1	31·0	31·0	30·9	30·7
Summer. April	29·3	29·1	29·1	29·1	29·1	29·0	29·1	29·3	29·5	29·1	28·3	27·5	27·2	27·3	27·6	28·1	28·6	29·0	29·1	29·3	29·3	29·3	29·3	29·3	29·3	28·8
May	29·6	29·7	29·6	29·6	29·5	29·6	29·7	29·9	29·8	29·2	28·5	27·9	27·7	27·9	28·3	28·8	29·1	29·5	29·7	29·8	29·8	29·8	29·7	29·7	29·7	29·3
June	30·8	30·8	30·8	30·7	30·7	30·8	30·8	30·9	30·8	30·4	29·8	29·2	28·9	28·9	29·1	29·6	30·4	30·8	31·1	31·1	31·0	31·0	30·9	30·8	30·8	30·4
July	31·4	31·4	31·4	31·4	31·4	31·4	31·6	31·5	31·3	30·8	30·2	29·6	29·3	29·8	29·5	30·0	30·7	31·2	31·6	31·6	31·6	31·5	31·5	31·5	31·5	30·9
Aug.	31·9	31·7	31·8	31·8	31·8	31·9	32·0	32·2	32·3	31·8	31·2	30·5	30·2	30·4	30·7	31·2	31·5	31·9	31·9	32·0	32·1	32·0	32·0	31·9	31·9	31·6
Sep.	32·2	32·2	32·1	32·1	32·1	32·1	32·3	32·7	33·0	32·7	32·1	31·5	31·1	30·7	31·0	31·6	32·1	32·4	32·5	32·5	32·6	32·7	32·5	32·4	32·3	32·1
Means	30·9	30·8	30·8	30·8	30·8	30·8	30·9	31·1	31·1	30·7	30·0	29·4	29·1	29·1	29·4	29·9	30·4	30·8	31·0	31·1	31·1	31·1	31·0	30·9	30·9	30·5

Diurnal Inequality of the Dip at Dehra Dun in 1915, deduced from the above Table.

Winter. Jan.	+0′·1	+0′·1	+0′·1	+0′·1	+0′·1	0′	−0′·1	−0′·2	−0′·2	−0′·2	−0′·1	−0′·5	−0′·8	−0′·6	−0′·3	−0′·1	0′	+0′·2	+0′·3	+0′·3	+0′·3	+0′·3	+0′·3	+0′·3	+0′·2	
Feb.	+0·2	+0·2	+0·1	+0·1	+0·1	0	0	0	+0·1	0	−0·3	−0·8	−1·0	−0·9	−0·7	−0·3	0	+0·2	+0·3	+0·4	+0·4	+0·4	+0·3	+0·4	+0·3	
Mar.	+0·2	+0·3	+0·1	+0·1	+0·1	+0·1	+0·1	+0·3	+0·4	+0·2	−0·5	−1·2	−1·2	−1·2	−0·8	−0·4	+0·1	+0·3	+0·5	+0·5	+0·4	+0·4	+0·3	+0·5	+0·3	
Oct.	+0·2	+0·4	+0·2	+0·2	+0·2	+0·2	+0·1	+0·4	+0·6	+0·4	−0·2	−1·0	−1·5	−1·4	−1·1	−0·5	0·2	+0·1	+0·4	+0·4	+0·4	+0·5	+0·5	+0·4	+0·1	
Nov.	+0·4	+0·2	+0·1	+0·2	0	+0·1	0	+0·2	+0·1	−0·1	−0·5	−0·9	−0·9	−0·6	−0·4	0	+0·2	+0·1	+0·2	+0·2	+0·2	+0·2	+0·1	0	0	
Dec.	+0·2	+0·2	+0·2	+0·1	0	0	0	−0·1	−0·1	0	−0·1	−0·4	−0·5	−0·3	−0·2	−0·2	−0·1	0	+0·1	+0·2	+0·2	+0·2	+0·1	+0·1	0	
Means	+0·3	+0·3	+0·2	+0·2	+0·1	+0·1	+0·1	+0·2	+0·2	+0·1	−0·2	−0·7	−0·9	−0·8	−0·5	−0·2	+0·1	+0·2	+0·4	+0·4	+0·4	+0·4	+0·3	+0·3	+0·2	
Summer. April	+0·5	+0·3	+0·3	+0·3	+0·3	+0·2	+0·3	+0·5	+0·7	+0·3	−0·5	−1·3	−1·6	−1·5	−1·2	−0·7	−0·2	+0·2	+0·3	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5	
May	+0·3	+0·4	+0·3	+0·3	+0·2	+0·3	+0·4	+0·6	+0·5	−0·1	−0·8	−1·4	−1·6	−1·4	−1·0	−0·5	−0·2	+0·2	+0·4	+0·5	+0·5	+0·5	+0·4	+0·4	+0·4	
June	+0·4	+0·4	+0·4	+0·3	+0·3	+0·4	+0·4	+0·5	+0·4	0	−0·6	−1·2	−1·5	−1·5	−1·3	−0·8	0	+0·4	+0·7	+0·7	+0·6	+0·6	+0·5	+0·4	+0·4	
July	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5	+0·7	+0·6	+0·4	−0·1	−0·7	−1·3	−1·6	−1·6	−1·4	−0·9	−0·2	+0·3	+0·7	+0·7	+0·7	+0·6	+0·6	+0·6	+0·6	
Aug.	+0·3	+0·1	+0·2	+0·2	+0·2	+0·3	+0·4	+0·6	+0·7	+0·2	−0·4	−1·1	−1·4	−1·2	−0·9	−0·4	−0·1	+0·3	+0·3	+0·4	+0·5	+0·4	+0·4	+0·3	+0·3	
Sep.	+0·1	0·1	0	0	0	0	+0·2	+0·6	+0·9	+0·6	0	−0·6	−1·0	−1·4	−1·1	−0·5	0	+0·3	+0·4	+0·4	+0·5	+0·6	+0·4	+0·3	+0·2	
Means	+0·4	+0·3	+0·3	+0·3	+0·3	+0·3	+0·4	+0·6	+0·6	+0·2	−0·5	−1·1	−1·4	−1·4	−1·1	−0·6	−0·1	+0·3	+0·5	+0·6	+0·6	+0·6	+0·5	+0·4	+0·4	

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

Digitized by Google

D.—*Hourly Means of the Declination at Barrackpore in 1915, determined from all available days. Declination = E. 0° + tabular quantity.*

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	29′·2	29′·2	29′·1	29′·0	28′·9	28′·6	28′·3	28′·3	29′·2	30′·3	29′·8	28′·4	28′·1	28′·5	29′·0	29′·3	29′·4	29′·3	29′·1	29′·2	29′·3	29′·2	29′·2	29′·2	29′·2	29′·0
Feb.	28·8	28·8	28·7	28·6	28·7	28·5	28·4	28·8	29·1	28·9	28·3	27·6	27·4	27·8	28·7	29·3	29·6	29·3	28·8	28·8	28·7	28·6	28·7	28·7	28·8	28·6
Mar.	28·5	28·4	28·4	28·2	28·0	28·0	28·0	28·8	30·0	30·3	29·8	28·4	27·0	26·2	26·5	27·6	28·6	28·8	28·3	28·2	28·1	28·2	28·3	28·3	28·5	28·3
Oct.																										
Nov.																										
Dec.																										
Means																										
Summer. April	27·9	28·1	28·1	28·1	28·0	27·9	28·2	29·4	30·2	30·1	29·0	26·8	25·1	24·6	25·3	26·6	27·6	27·9	27·8	27·5	27·4	27·5	27·7	27·7	27·9	27·7
May																										
June																										
July																										
Aug.																										
Sep.																										
Means																										

Diurnal Inequality of the Declination at Barrackpore in 1915, deduced from the above Table.

Winter. Jan.	+ 0′·2	+ 0′·2	+ 0′·1	0′	− 0′·1	− 0′·4	− 0′·7	− 0′·7	+ 0′·2	+ 1′·3	+ 0′·8	− 0′·6	− 0′·9	− 0′·5	0′	+ 0′·3	+ 0′·4	+ 0′·3	+ 0′·1	+ 0′·2	+ 0′·3	+ 0′·2	+ 0′·2	+ 0′·2	+ 0′·2	
Feb.	+ 0·2	+ 0·2	+ 0·1	0	+ 0·1	− 0·1	− 0·2	+ 0·2	+ 0·5	+ 0·3	− 0·3	− 1·0	− 1·2	− 0·8	+ 0·1	+ 0·7	+ 1·0	+ 0·7	+ 0·2	+ 0·2	+ 0·1	0	+ 0·1	+ 0·1	+ 0·2	
Mar.	+ 0·2	+ 0·1	+ 0·1	− 0·1	− 0·3	− 0·3	− 0·3	+ 0·5	+ 1·7	+ 2·0	+ 1·5	+ 0·1	− 1·3	− 2·1	− 1·8	− 0·7	+ 0·3	+ 0·5	0	− 0·1	− 0·2	− 0·1	0	0	+ 0·2	
Oct.																										
Nov.																										
Dec.																										
Means																										
Summer. April	+ 0·2	+ 0·4	+ 0·4	+ 0·4	+ 0·3	+ 0·2	+ 0·5	+ 1·7	+ 2·5	+ 2·4	+ 1·3	− 0·9	− 2·6	− 3·1	− 2·4	− 1·1	− 0·1	+ 0·2	+ 0·1	− 0·2	− 0·3	− 0·2	0	0	+ 0·2	
May																										
June																										
July																										
Aug.																										
Sep.																										
Means																										

NOTE.—When the sign is + the Magnet points to the East, and when − to the West of the mean position.

Digitized by Google

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Barrackpore in 1915, from all available days. Horizontal Force = ·37000 C.G.S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter. Jan.	390	393	393	393	395	396	398	401	406	407	407	410	**413**	412	405	401	396	391	390	388	389	388	**388**	390	390	398
Winter. Feb.	386	387	388	391	392	391	395	395	397	399	407	416	**420**	419	413	406	397	391	387	386	**383**	384	384	388	386	396
Winter. Mar.	388	391	391	392	395	394	395	395	401	408	419	**425**	424	419	414	405	396	392	387	**384**	385	385	385	387	387	398
Winter. Oct.																										
Winter. Nov.																										
Winter. Dec.																										
Means																										
Summer. April	388	391	392	392	392	394	396	395	396	405	418	429	**430**	427	423	415	406	399	394	389	**387**	388	390	390	389	401
Summer. May																										
Summer. June																										
Summer. July																										
Summer. Aug.																										
Summer. Sep.																										
Means																										

Diurnal Inequality of the Horizontal Force at Barrackpore in 1915, deduced from the above Table.

	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter. Jan.	− 8	− 5	− 5	− 5	− 3	− 2	0	+ 3	+ 8	+ 9	+ 9	+ 12	+ 15	+ 14	+ 7	+ 3	− 2	− 7	− 8	− 10	− 9	− 10	− 10	− 8	− 8	
Winter. Feb.	− 10	− 9	− 8	− 5	− 4	− 5	− 1	− 1	+ 1	+ 3	+ 11	+ 20	+ 24	+ 23	+ 17	+ 10	+ 1	− 5	− 9	− 10	− 13	− 12	− 12	− 8	− 10	
Winter. Mar.	− 10	− 7	− 7	− 6	− 3	− 4	− 3	− 3	+ 3	+ 10	+ 21	+ 27	+ 26	+ 21	+ 16	+ 7	− 2	− 6	− 11	− 14	− 13	− 13	− 13	− 11	− 11	
Winter. Oct.																										
Winter. Nov.																										
Winter. Dec.																										
Means																										
Summer. April	− 13	− 10	− 9	− 9	− 9	− 7	− 5	− 6	− 5	+ 4	+ 17	+ 28	+ 29	+ 26	+ 22	+ 14	+ 5	− 2	− 7	− 12	− 14	− 13	− 11	− 11	− 12	
Summer. May																										
Summer. June																										
Summer. July																										
Summer. Aug.																										
Summer. Sep.																										
Means																										

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Barrackpore in 1915, from all available days. Vertical Force = ·22000 C.G.S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter. Jan.	491	491	491	492	492	493	494	494	494	489	483	480	482	482	484	487	489	490	491	491	491	491	491	492	491	489
Winter. Feb.	497	498	498	498	498	499	499	500	499	495	492	490	489	490	490	492	493	494	496	496	497	497	497	498	498	496
Winter. Mar.	503	504	504	505	505	505	505	507	505	500	496	491	489	490	495	498	498	499	500	501	502	503	504	504	505	501
Winter. Oct.																										
Winter. Nov.																										
Winter. Dec.																										
Means																										
Summer. April	509	510	510	510	510	511	513	513	510	503	496	490	493	498	503	505	505	505	506	506	507	509	509	509	509	506
Summer. May																										
Summer. June																										
Summer. July																										
Summer. Aug.																										
Summer. Sep.																										
Means																										

Diurnal Inequality of the Vertical Force at Barrackpore in 1915, deduced from the above Table.

	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter. Jan.	+ 2	+ 2	+ 2	+ 3	+ 3	+ 4	+ 5	+ 5	+ 5	0	− 6	− 9	− 7	− 7	− 5	− 2	0	+ 1	+ 2	+ 2	+ 2	+ 2	+ 2	+ 3	+ 2	
Winter. Feb.	+ 1	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	+ 4	+ 3	− 1	− 4	− 6	− 7	− 6	− 6	− 4	− 3	− 2	0	0	+ 1	+ 1	+ 1	+ 2	+ 2	
Winter. Mar.	+ 2	+ 3	+ 3	+ 4	+ 4	+ 4	+ 4	+ 6	+ 4	− 1	− 5	− 10	− 12	− 11	− 6	− 3	− 3	− 2	− 1	0	+ 1	+ 2	+ 3	+ 3	+ 4	
Winter. Oct.																										
Winter. Nov.																										
Winter. Dec.																										
Means																										
Summer. April	+ 3	+ 4	+ 4	+ 4	+ 4	+ 5	+ 7	+ 7	+ 4	− 3	− 10	− 16	− 13	− 8	− 3	− 1	− 1	− 1	0	0	+ 1	+ 3	+ 3	+ 3	+ 3	
Summer. May																										
Summer. June																										
Summer. July																										
Summer. Aug.																										
Summer. Sep.																										
Means																										

NOTE.—When the sign is + the V.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of the Dip at Barrackpore in 1915, determined from all available days. Dip = N. 31° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	1′·7	1′·6	1′·6	1′·6	1′·6	1′·6	1′·6	1′·5	1′·3	0′·9	0′·4	0′·1	0′·1	0′·2	0′·6	1′·0	1′·3	1′·6	1′·7	1′·8	1′·7	1′·8	1′·8	1′·7	1′·7	1′·3
Feb.	2·2	2·3	2·2	2·1	2·1	2·2	2·0	2·1	1·9	1·6	1·1	0·6	0·3	0·4	0·7	1·1	1·5	1·8	2·2	2·2	2·4	2·3	2·3	2·2	2·3	1·7
Mar.	2·6	2·5	2·5	2·5	2·4	2·5	2·4	2·6	2·2	1·6	0·9	0·3	0·2	0·4	1·0	1·5	1·9	2·1	2·4	2·6	2·6	2·7	2·8	2·7	2·8	2·0
Oct.																										
Nov.																										
Dec.																										
Means																										
Summer. April	3·0	2·9	2·9	2·9	2·9	2·9	2·9	3·0	2·7	1·9	0·9	0·0	0·2	0·6	1·1	1·6	2·0	2·3	2·5	2·8	2·9	3·0	2·9	2·9	3·0	2·2
May																										
June																										
July																										
Aug.																										
Sep.																										
Means																										

Diurnal Inequality of the Dip at Barrackpore in 1915, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	+0′·4	+0′·3	+0′·3	+0′·3	+0′·3	+0′·3	+0′·3	+0′·2	0′	−0′·4	−0′·9	−1′·2	−1′·2	−1′·1	−0′·7	−0′·3	0′	+0′·3	+0′·4	+0′·5	+0′·4	+0′·5	+0′·5	+0′·4	+0′·4	
Feb.	+0·5	+0·6	+0·5	+0·4	+0·4	+0·5	+0·3	+0·4	+0·2	−0·1	−0·6	−1·1	−1·4	−1·3	−1·0	−0·6	−0·2	+0·1	+0·5	+0·5	+0·7	+0·6	+0·6	+0·5	+0·6	
Mar.	+0·6	+0·5	+0·5	+0·5	+0·4	+0·5	+0·4	+0·6	+0·2	−0·4	−1·1	−1·7	−1·8	−1·6	−1·0	−0·5	−0·1	+0·1	+0·4	+0·6	+0·6	+0·7	+0·8	+0·7	+0·8	
Oct.																										
Nov.																										
Dec.																										
Means																										
Summer. April	+0·8	+0·7	+0·7	+0·7	+0·7	+0·7	+0·7	+0·8	+0·5	−0·3	−1·3	−2·2	−2·0	−1·6	−1·1	−0·6	−0·2	+0·1	+0·3	+0·6	+0·7	+0·8	+0·7	+0·7	+0·8	
May																										
June																										
July																										
Aug.																										
Sep.																										
Means																										

Note.—When the sign is + the Dip is greater, and when − it is less than the mean.

Digitized by Google

E.—*Hourly Means of the Declination at Toungoo in 1915, determined from all available days. Declination = W. 0° + tabular quantity.*

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	0′·5	0′·5	0′·6	0′·7	0′·9	1′·0	1′·2	1′·2	0′·5	− 0′·5	− 0′·2	0′·8	1′·1	0′·9	0′·5	0′·2	0′·0	0′·2	0′·4	0′·4	0′·3	0′·5	0′·6	0′·5	0′·5	0′·5
Winter. Feb.	0·9	0·9	1·0	1·0	1·1	1·1	1·3	1·0	0·7	0·9	1·4	1·8	1·9	1·6	1·0	0·5	0·0	0·3	0·9	0·8	0·9	1·1	1·1	1·0	1·0	1·0
Winter. Mar.	1·3	1·3	1·3	1·4	1·6	1·7	1·7	0·9	0·0	− 0·4	− 0·1	0·8	2·0	2·7	2·7	1·9	1·2	1·1	1·4	1·4	1·5	1·5	1·5	1·5	1·3	1·3
Winter. Oct.	5·1	5·1	4·9	5·0	5·0	5·3	5·1	4·3	3·9	4·1	4·7	5·6	6·3	6·5	5·9	5·1	4·5	4·7	5·1	5·0	5·2	5·2	5·2	5·2	5·1	5·1
Winter. Nov.	5·5	5·3	5·5	5·4	5·6	5·8	5·7	5·3	5·0	5·2	5·7	6·2	6·1	5·4	5·0	4·8	4·7	5·3	5·3	5·3	5·3	5·5	5·5	5·6	5·5	5·4
Winter. Dec.	6·0	6·1	6·1	6·2	6·3	6·3	6·3	6·2	5·6	5·1	5·5	6·3	6·8	6·6	6·3	5·7	5·3	5·6	5·7	5·7	5·8	5·9	6·0	6·1	6·1	6·0
Means	3·2	3·2	3·2	3·3	3·4	3·5	3·6	3·2	2·6	2·4	2·8	3·6	4·0	4·0	3·6	3·0	2·6	2·9	3·1	3·1	3·2	3·3	3·3	3·3	3·3	3·2
Summer. April	1·4	1·3	1·2	1·2	1·3	1·5	1·1	0·1	− 0·4	− 0·2	0·7	2·3	3·7	3·9	3·4	2·6	1·6	1·2	1·6	1·9	1·9	1·9	1·9	1·6	1·4	1·6
Summer. May	2·1	2·0	1·9	1·8	2·0	1·9	0·7	0·0	0·0	1·0	2·3	3·2	4·0	3·8	3·2	2·6	2·0	1·8	2·0	2·5	2·6	2·6	2·5	2·4	2·1	2·1
Summer. June	2·4	2·2	2·1	2·1	2·1	2·0	0·9	0·1	0·1	1·0	2·1	3·4	4·2	4·4	4·1	3·7	2·9	2·4	2·3	2·6	2·8	2·9	2·8	2·7	2·5	2·4
Summer. July	3·3	3·1	3·0	2·9	2·8	2·6	1·3	0·3	0·2	1·2	2·4	3·8	4·9	5·0	4·8	4·4	3·6	3·1	2·9	3·3	3·4	3·4	3·4	3·4	3·3	3·0
Summer. Aug.	4·0	3·9	3·9	3·8	3·7	3·5	2·1	1·1	1·3	2·6	4·0	5·1	5·8	5·9	5·5	5·1	4·2	3·7	3·7	4·0	4·2	4·2	4·2	4·2	4·0	3·9
Summer. Sep.	4·4	4·3	4·1	4·2	4·2	4·1	3·1	2·0	2·1	3·4	4·9	6·2	7·2	7·1	6·2	5·0	3·9	3·8	4·3	4·5	4·6	4·7	4·7	4·7	4·5	4·5
Means	2·9	2·8	2·7	2·7	2·7	2·6	1·5	0·6	0·6	1·5	2·7	4·0	5·0	5·0	4·5	3·9	3·0	2·7	2·8	3·1	3·3	3·3	3·3	3·2	3·0	2·9

—sign indicates that the Declination is East.

Diurnal Inequality of the Declination at Toungoo in 1915, deduced from the above Table.

Winter. Jan.	0′	0′	− 0′·1	− 0′·2	− 0′·4	− 0′·5	− 0′·7	− 0′·7	0′	+ 1′·0	+ 0′·7	− 0′·3	− 0′·6	− 0′·4	0′	+ 0′·3	+ 0′·5	+ 0′·3	+ 0′·1	+ 0′·1	+ 0′·2	0′	− 0′·1	0′	0′	
Winter. Feb.	+ 0·1	+ 0·1	0	0	− 0·1	− 0·1	− 0·3	0	+ 0·3	+ 0·1	− 0·4	− 0·8	− 0·9	− 0·6	0	+ 0·5	+ 1·0	+ 0·7	+ 0·1	+ 0·2	+ 0·1	− 0·1	− 0·1	0	0	
Winter. Mar.	0	0	0	− 0·1	− 0·3	− 0·4	− 0·4	+ 0·4	+ 1·3	+ 1·7	+ 1·4	+ 0·5	− 0·7	− 1·4	− 1·4	− 0·6	+ 0·1	+ 0·2	− 0·1	− 0·1	− 0·2	− 0·2	− 0·2	− 0·2	0	
Winter. Oct.	0	0	+ 0·2	+ 0·1	+ 0·1	− 0·2	0	+ 0·8	+ 1·2	+ 1·0	+ 0·4	− 0·5	− 1·2	− 1·4	− 0·8	0	+ 0·6	+ 0·4	0	+ 0·1	− 0·1	− 0·1	− 0·1	− 0·1	0	
Winter. Nov.	− 0·1	+ 0·1	− 0·1	0	− 0·2	− 0·4	− 0·3	+ 0·1	+ 0·4	+ 0·2	− 0·3	− 0·8	− 0·7	0	+ 0·4	+ 0·6	+ 0·7	+ 0·1	+ 0·1	+ 0·1	+ 0·1	− 0·1	− 0·1	− 0·2	− 0·1	
Winter. Dec.	0	− 0·1	− 0·1	− 0·2	− 0·3	− 0·3	− 0·3	− 0·2	+ 0·4	+ 0·9	+ 0·5	− 0·3	− 0·8	− 0·6	− 0·3	+ 0·3	+ 0·7	+ 0·4	+ 0·3	+ 0·3	+ 0·2	+ 0·1	0	− 0·1	− 0·1	
Means	0	0	0	− 0·1	− 0·2	− 0·3	− 0·4	0	+ 0·6	+ 0·8	+ 0·4	− 0·4	− 0·8	− 0·8	− 0·4	+ 0·2	+ 0·6	+ 0·3	+ 0·1	+ 0·1	0	− 0·1	− 0·1	− 0·1	− 0·1	
Summer. April	+ 0·2	+ 0·3	+ 0·4	+ 0·4	+ 0·3	+ 0·1	+ 0·5	+ 1·5	+ 2·0	+ 1·8	+ 0·9	− 0·7	− 2·1	− 2·3	− 1·8	− 1·0	0	+ 0·4	0	− 0·3	− 0·3	− 0·3	− 0·3	0	+ 0·2	
Summer. May	0	+ 0·1	+ 0·2	+ 0·3	+ 0·1	+ 0·2	+ 1·4	+ 2·1	+ 2·1	+ 1·1	− 0·2	− 1·1	− 1·9	− 1·7	− 1·1	− 0·5	+ 0·1	+ 0·3	+ 0·1	− 0·4	− 0·5	− 0·5	− 0·4	− 0·3	0	
Summer. June	0	+ 0·2	+ 0·3	+ 0·3	+ 0·3	+ 0·4	+ 1·5	+ 2·3	+ 2·3	+ 1·4	+ 0·3	− 1·0	− 1·8	− 2·0	− 1·7	− 1·3	− 0·5	0	+ 0·1	− 0·2	− 0·4	− 0·5	− 0·4	− 0·3	− 0·1	
Summer. July	− 0·3	− 0·1	0	+ 0·1	+ 0·2	+ 0·4	+ 1·7	+ 2·7	+ 2·8	+ 1·8	+ 0·6	− 0·8	− 1·9	− 2·0	− 1·8	− 1·4	− 0·6	− 0·1	+ 0·1	− 0·3	− 0·4	− 0·4	− 0·4	− 0·4	− 0·3	
Summer. Aug.	− 0·1	0	0	+ 0·1	+ 0·2	+ 0·4	+ 1·8	+ 2·8	+ 2·6	+ 1·3	− 0·1	− 1·2	− 1·9	− 2·0	− 1·6	− 1·2	− 0·3	+ 0·2	+ 0·2	− 0·1	− 0·3	− 0·3	− 0·3	− 0·3	− 0·1	
Summer. Sep.	+ 0·1	+ 0·2	+ 0·4	+ 0·3	+ 0·3	+ 0·4	+ 1·4	+ 2·5	+ 2·4	+ 1·1	− 0·4	− 1·7	− 2·7	− 2·6	− 1·7	− 0·5	+ 0·6	+ 0·7	+ 0·2	0	− 0·1	− 0·2	− 0·2	− 0·2	0	
Means	0	+ 0·1	+ 0·2	+ 0·2	+ 0·2	+ 0·3	+ 1·4	+ 2·3	+ 2·3	+ 1·4	+ 0·2	− 1·1	− 2·1	− 2·1	− 1·6	− 1·0	− 0·1	+ 0·2	+ 0·1	− 0·2	− 0·4	− 0·4	− 0·4	− 0·3	− 0·1	

NOTE.—When the sign is + the Magnet points to the East, and when − to the West of the mean position.

Digitized by Google

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Toungoo in 1915, from all available days. Horizontal Force = ·38000 C.G.S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter. Jan.	992	992	995	994	996	997	1000	1005	1011	1015	1019	1019	**1022**	1016	1006	1000	997	993	990	989	**989**	990	990	991	992	1000
Feb.	993	993	993	996	997	997	998	1002	1007	1015	1023	1030	**1034**	1029	1020	1010	1001	996	993	991	**988**	989	990	994	992	1003
Mar.	990	995	995	995	998	998	998	999	1006	1019	1031	**1040**	1039	1030	1020	1009	997	993	991	990	**989**	990	991	994	990	1004
Oct.	994	999	997	999	999	1000	998	997	1002	1012	1026	1038	**1041**	1034	1024	1013	1002	1000	999	995	993	994	**992**	994	995	1006
Nov.	**988**	990	992	994	994	995	994	997	1004	1010	1019	**1026**	1025	1017	1007	998	996	991	990	991	990	990	994	995	996	999
Dec.	**1001**	1003	1002	1004	1005	1006	1008	1011	1016	1018	1023	1026	**1031**	1025	1017	1012	1008	1005	1005	1003	1001	1001	1002	1004	1004	1010
Means	993	995	996	997	998	999	999	1002	1008	1015	1024	1030	**1032**	1025	1016	1007	1000	996	995	993	**992**	992	993	995	995	1004
Summer. April	987	**987**	989	991	991	992	992	994	1001	1016	1034	1043	**1043**	1034	1022	1010	999	992	991	989	988	987	987	987	988	1002
May	999	1001	999	1001	1000	1003	1003	1003	1010	1021	1032	1039	**1040**	1033	1024	1013	1005	1000	1000	1000	999	998	**998**	998	999	1009
June	991	994	994	994	995	996	998	1002	1009	1017	1026	1030	**1032**	1029	1021	1010	999	990	**988**	989	989	989	991	992	993	1003
July	994	994	995	995	996	995	998	1003	1011	1018	1029	1034	**1037**	1032	1025	1013	1002	994	991	991	**991**	992	992	994	995	1005
Aug.	995	995	998	998	1000	998	999	1000	1005	1013	1024	1029	**1033**	1031	1022	1012	1001	994	**993**	994	994	993	995	994	995	1005
Sep.	1000	1004	1003	1005	1006	1006	1005	1001	1004	1017	1031	1038	**1042**	1037	1028	1017	1006	1001	997	997	997	**995**	996	999	1000	1010
Means	994	996	996	997	998	998	999	1001	1007	1017	1029	1036	**1038**	1033	1024	1013	1002	995	993	993	993	**992**	993	994	995	1006

Diurnal Inequality of the Horizontal Force at Toungoo in 1915, deduced from the above Table.

	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter. Jan.	− 8	− 8	− 5	− 6	− 4	− 3	0	+ 5	+ 11	+ 15	+ 19	+ 19	+ 22	+ 16	+ 6	0	− 3	− 7	− 10	− 11	− 11	− 10	− 10	− 9	− 8	
Feb.	− 10	− 10	− 10	− 7	− 6	− 6	− 5	− 1	+ 4	+ 12	+ 20	+ 27	+ 31	+ 26	+ 17	+ 7	− 2	− 7	− 10	− 12	− 15	− 14	− 13	− 9	− 11	
Mar.	− 14	− 9	− 9	− 9	− 6	− 6	− 6	− 5	+ 2	+ 15	+ 27	+ 36	+ 35	+ 26	+ 16	+ 5	− 7	− 11	− 13	− 14	− 15	− 14	− 13	− 10	− 14	
Oct.	− 12	− 7	− 9	− 7	− 7	− 6	− 8	− 9	− 4	+ 6	+ 20	+ 32	+ 35	+ 28	+ 18	+ 7	− 4	− 6	− 7	− 11	− 13	− 12	− 14	− 12	− 11	
Nov.	− 11	− 9	− 7	− 5	− 5	− 4	− 5	− 2	+ 5	+ 11	+ 20	+ 27	+ 26	+ 18	+ 8	− 1	− 3	− 8	− 9	− 8	− 9	− 9	− 5	− 4	− 3	
Dec.	− 9	− 7	− 8	− 6	− 5	− 4	− 2	+ 1	+ 6	+ 8	+ 13	+ 16	+ 21	+ 15	+ 7	+ 2	− 2	− 5	− 5	− 7	− 9	− 9	− 8	− 6	− 6	
Means	− 11	− 9	− 8	− 7	− 6	− 5	− 5	− 2	+ 4	+ 11	+ 20	+ 26	+ 28	+ 21	+ 12	+ 3	− 4	− 8	− 9	− 11	− 12	− 12	− 11	− 9	− 9	
Summer. April	− 15	− 15	− 13	− 11	− 11	− 10	− 10	− 8	− 1	+ 14	+ 32	+ 41	+ 41	+ 32	+ 20	+ 8	− 3	− 10	− 11	− 13	− 14	− 15	− 15	− 15	− 14	
May	− 10	− 8	− 10	− 8	− 9	− 6	− 6	− 6	+ 1	+ 12	+ 23	+ 30	+ 31	+ 24	+ 15	+ 4	− 4	− 9	− 9	− 9	− 10	− 11	− 11	− 11	− 10	
June	− 12	− 9	− 9	− 9	− 8	− 7	− 5	− 1	+ 6	+ 14	+ 23	+ 27	+ 29	+ 26	+ 18	+ 7	− 4	− 13	− 15	− 14	− 14	− 14	− 12	− 11	− 10	
July	− 11	− 11	− 10	− 10	− 9	− 10	− 7	− 2	+ 6	+ 13	+ 24	+ 29	+ 32	+ 27	+ 20	+ 8	− 3	− 11	− 14	− 14	− 14	− 13	− 13	− 11	− 10	
Aug.	− 10	− 10	− 7	− 7	− 5	− 7	− 6	− 5	0	+ 8	+ 19	+ 24	+ 28	+ 26	+ 17	+ 7	− 4	− 11	− 12	− 11	− 11	− 12	− 10	− 11	− 10	
Sep.	− 10	− 6	− 7	− 5	− 4	− 4	− 5	− 9	− 6	+ 7	+ 21	+ 28	+ 32	+ 27	+ 18	+ 7	− 4	− 9	− 13	− 13	− 13	− 15	− 14	− 11	− 10	
Means	− 12	− 10	− 10	− 9	− 8	− 8	− 7	− 5	+ 1	+ 11	+ 23	+ 30	+ 32	+ 27	+ 18	+ 7	− 4	− 11	− 13	− 13	− 13	− 14	− 13	− 12	− 11	

NOTE:—When the sign is + the H.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Toungoo in 1915, from all available days. Vertical Force = ·16000 C.G.S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter. Jan.	647	647	647	647	647	647	647	646	647	641	631	**628**	632	638	642	645	646	645	646	647	647	647	648	**648**	648	644
Feb.	650	651	650	651	651	650	650	650	646	639	634	**633**	636	642	647	648	648	646	647	649	649	649	650	651	**651**	647
Mar.	653	653	653	653	652	652	**653**	653	652	645	638	635	**633**	636	643	648	650	648	648	650	651	651	652	653	653	648
Oct.	664	664	664	664	664	664	666	**666**	661	652	645	**642**	645	652	659	662	660	658	659	661	661	662	663	664	665	659
Nov.	666	667	666	666	666	667	**667**	667	663	657	**652**	652	655	659	659	661	661	660	663	664	665	666	667	667	667	663
Dec.	666	666	666	666	666	667	667	**667**	667	661	653	647	649	653	659	662	664	662	663	665	665	665	665	666	666	662
Means	658	658	658	658	658	658	**658**	658	656	649	642	**640**	642	647	652	654	655	653	654	656	656	657	658	658	658	654
Summer. April	654	655	654	654	654	654	**657**	656	649	641	632	**628**	629	638	647	652	653	651	649	649	650	651	652	653	653	648
May	652	652	652	652	652	653	**656**	654	649	641	636	**636**	638	644	648	652	654	652	649	649	649	651	651	652	652	649
June	663	663	663	663	663	664	**666**	664	658	650	646	**645**	647	653	657	660	663	662	661	660	661	662	663	663	663	659
July	656	657	656	656	657	657	**662**	659	652	644	640	**639**	642	646	651	653	657	657	655	653	654	656	656	657	657	653
Aug.	657	658	658	658	658	659	**664**	660	651	641	638	**637**	638	643	648	652	656	657	655	654	655	656	657	658	658	653
Sep.	65	660	660	660	660	660	**665**	662	651	638	632	**631**	634	644	654	659	659	656	654	656	657	658	659	660	660	654
Means	657	658	657	657	657	658	**662**	659	652	643	637	**636**	638	645	651	655	657	656	654	654	654	656	656	657	657	653

Diurnal Inequality of the Vertical Force at Toungoo in 1915, deduced from the above Table.

	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter. Jan.	+ 3	+ 3	+ 3	+ 3	+ 3	+ 3	+ 3	+ 2	+ 3	− 3	− 13	− 16	− 12	− 6	− 2	+ 1	+ 2	+ 1	+ 2	+ 3	+ 3	+ 3	+ 4	+ 4	+ 4	
Feb.	+ 3	+ 4	+ 3	+ 4	+ 4	+ 3	+ 3	+ 3	− 1	− 8	− 13	− 14	− 11	− 5	0	+ 1	+ 1	− 1	0	+ 2	+ 2	+ 2	+ 3	+ 4	+ 4	
Mar.	+ 5	+ 5	+ 5	+ 5	+ 4	+ 4	+ 5	+ 5	+ 4	− 3	− 10	− 13	− 15	− 12	− 5	0	+ 2	0	0	+ 2	+ 3	+ 3	+ 4	+ 5	+ 5	
Oct.	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	+ 7	+ 7	+ 2	− 7	− 14	− 17	− 14	− 7	0	+ 3	+ 1	− 1	0	+ 2	+ 2	+ 3	+ 4	+ 5	+ 6	
Nov.	+ 3	+ 4	+ 3	+ 3	+ 3	+ 4	+ 4	+ 4	0	− 6	− 11	− 11	− 8	− 4	− 4	− 2	− 2	− 3	0	+ 1	+ 2	+ 3	+ 4	+ 4	+ 4	
Dec.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 5	+ 5	+ 5	+ 5	− 1	− 9	− 15	− 13	− 9	− 3	0	+ 2	0	+ 1	+ 3	+ 3	+ 3	+ 3	+ 4	+ 4	
Means	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 2	− 5	− 12	− 14	− 12	− 7	− 2	0	+ 1	− 1	0	+ 2	+ 2	+ 3	+ 4	+ 4	+ 4	
Summer. April	+ 6	+ 7	+ 6	+ 6	+ 6	+ 6	+ 9	+ 8	+ 1	− 7	− 16	− 20	− 19	− 10	− 1	+ 4	+ 5	+ 3	+ 1	+ 1	+ 2	+ 3	+ 4	+ 5	+ 5	
May	+ 3	+ 3	+ 3	+ 3	+ 3	+ 4	+ 7	+ 5	0	− 8	− 13	− 13	− 11	− 5	− 1	+ 3	+ 5	+ 3	0	0	0	+ 2	+ 2	+ 3	+ 3	
June	+ 4	+ 4	+ 4	+ 4	+ 4	+ 5	+ 7	+ 5	− 1	− 9	− 13	− 14	− 12	− 6	− 2	+ 1	+ 4	+ 3	+ 2	+ 1	+ 2	+ 3	+ 4	+ 4	+ 4	
July	+ 3	+ 4	+ 3	+ 3	+ 4	+ 4	+ 9	+ 6	− 1	− 9	− 13	− 14	− 11	− 7	− 2	0	+ 4	+ 4	+ 2	0	+ 1	+ 3	+ 3	+ 4	+ 4	
Aug.	+ 4	+ 5	+ 5	+ 5	+ 5	+ 6	+ 11	+ 7	− 2	− 12	− 15	− 16	− 15	− 10	− 5	− 1	+ 3	+ 4	+ 2	+ 1	+ 2	+ 3	+ 4	+ 5	+ 5	
Sep.	+ 5	+ 6	+ 6	+ 6	+ 6	+ 6	+ 11	+ 8	− 3	− 16	− 22	− 23	− 20	− 10	0	+ 5	+ 5	+ 2	0	+ 2	+ 3	+ 4	+ 5	+ 6	+ 6	
Means	+ 4	+ 5	+ 4	+ 4	+ 4	+ 5	+ 9	+ 6	− 1	− 10	− 16	− 17	− 15	− 8	− 2	+ 2	+ 4	+ 3	+ 1	+ 1	+ 1	+ 3	+ 3	+ 4	+ 4	

NOTE.—When the sign is + the V.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of the Dip at Toungoo in 1915, determined from all available days. Dip = N. 23° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	7′·2	7′·2	7′·1	7′·1	7′·0	7′·0	6′·9	6′·7	6′·6	6′·0	5′·1	4′·9	5′·1	5′·7	6′·4	6′·8	6′·9	7′·0	7′·2	7′·3	7′·3	7′·2	7′·3	7′·3	7′·2	6′·7
Feb.	7·3	7·4	7·3	7·3	7·3	7·2	7·2	7·0	6·6	5·8	5·2	4·9	5·0	5·6	6·3	6·6	6·9	7·0	7·1	7·4	7·4	7·4	7·4	7·4	7·4	6·8
Mar.	7·7	7·5	7·5	7·5	7·4	7·4	7·4	7·4	7·1	6·1	5·2	4·7	4·6	5·1	6·0	6·7	7·2	7·2	7·3	7·4	7·6	7·5	7·6	7·5	7·7	6·9
Oct.	8·4	8·2	8·3	8·2	8·2	8·2	8·4	8·4	7·9	6·9	5·9	5·3	5·4	6·2	7·0	7·6	7·8	7·7	7·8	8·1	8·2	8·2	8·3	8·4	8·4	7·6
Nov.	8·7	8·7	8·6	8·5	8·5	8·6	8·6	8·5	8·0	7·3	6·7	6·5	6·7	7·3	7·6	8·0	8·1	8·2	8·4	8·5	8·6	8·7	8·6	8·6	8·5	8·1
Dec.	8·3	8·2	8·2	8·2	8·2	8·2	8·2	8·0	7·9	7·4	6·6	6·1	6·1	6·6	7·3	7·6	7·9	7·9	7·9	8·2	8·2	8·2	8·2	8·2	8·2	7·7
Means	7·9	7·9	7·8	7·8	7·8	7·8	7·8	7·7	7·4	6·6	5·8	5·4	5·5	6·1	6·8	7·2	7·5	7·5	7·6	7·8	7·9	7·9	7·9	7·9	7·9	7·3
Summer. April	7·8	7·9	7·8	7·7	7·7	7·7	7·9	7·8	7·0	6·0	4·7	4·1	4·2	5·2	6·2	7·0	7·4	7·4	7·4	7·4	7·5	7·6	7·7	7·8	7·7	7·0
May	7·3	7·2	7·3	7·2	7·3	7·2	7·5	7·3	6·7	5·8	5·1	4·8	5·0	5·6	6·2	6·9	7·3	7·3	7·1	7·1	7·1	7·3	7·3	7·4	7·3	6·8
June	8·4	8·3	8·3	8·3	8·2	8·3	8·4	8·1	7·4	6·6	6·0	5·8	5·9	6·4	7·0	7·6	8·1	8·4	8·3	8·2	8·3	8·4	8·4	8·3	8·3	7·7
July	7·8	7·8	7·7	7·7	7·8	7·8	8·1	7·7	6·9	6·1	5·4	5·2	5·4	5·8	6·4	6·9	7·6	7·8	7·8	7·6	7·7	7·8	7·8	7·8	7·8	7·2
Aug.	7·8	7·9	7·8	7·8	7·7	7·9	8·2	7·9	7·0	6·0	5·5	5·2	5·2	5·6	6·3	6·9	7·5	7·8	7·7	7·6	7·7	7·8	7·8	7·9	7·9	7·2
Sep.	7·8	7·8	7·8	7·7	7·7	7·7	8·1	8·0	7·1	5·7	4·8	4·5	4·6	5·5	6·5	7·3	7·6	7·5	7·5	7·7	7·8	7·9	7·9	7·9	7·9	7·1
Means	7·8	7·8	7·8	7·7	7·7	7·8	8·0	7·8	7·0	6·0	5·3	4·9	5·1	5·7	6·4	7·1	7·6	7·7	7·6	7·6	7·7	7·8	7·8	7·9	7·8	7·2

Diurnal Inequality of the Dip at Toungoo in 1915, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	+0′·5	+0′·5	+0′·4	+0′·4	+0′·3	+0′·3	+0′·2	0′	−0′·1	−0′·7	−1′·6	−1′·8	−1′·6	−1′·0	−0′·3	+0′·1	+0′·2	+0′·3	+0′·5	+0′·6	+0′·6	+0′·5	+0′·6	+0′·6	+0′·5	
Feb.	+0·5	+0·6	+0·5	+0·5	+0·5	+0·4	+0·4	+0·2	−0·2	−1·0	−1·6	−1·9	−1·8	−1·2	−0·5	−0·2	+0·1	+0·2	+0·3	+0·6	+0·6	+0·6	+0·6	+0·6	+0·6	
Mar.	+0·8	+0·6	+0·6	+0·6	+0·5	+0·5	+0·5	+0·5	+0·2	−0·8	−1·7	−2·2	−2·3	−1·8	−0·9	−0·2	+0·3	+0·3	+0·4	+0·5	+0·7	+0·6	+0·7	+0·6	+0·8	
Oct.	+0·8	+0·6	+0·7	+0·6	+0·6	+0·6	+0·8	+0·8	+0·3	−0·7	−1·7	−2·3	−2·2	−1·4	−0·6	0	+0·2	+0·1	+0·2	+0·5	+0·6	+0·6	+0·7	+0·8	+0·8	
Nov.	+0·6	+0·6	+0·5	+0·4	+0·4	+0·5	+0·5	+0·4	−0·1	−0·8	−1·4	−1·6	−1·4	−0·8	−0·5	−0·1	0	+0·1	+0·3	+0·4	+0·5	+0·6	+0·5	+0·5	+0·4	
Dec.	+0·6	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5	+0·3	+0·2	−0·3	−1·1	−1·6	−1·6	−1·1	−0·4	−0·1	+0·2	+0·2	+0·2	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5	
Means	+0·6	+0·6	+0·5	+0·5	+0·5	+0·5	+0·5	+0·4	+0·1	−0·7	−1·5	−1·9	−1·8	−1·2	−0·5	−0·1	+0·2	+0·2	+0·3	+0·5	+0·6	+0·6	+0·6	+0·6	+0·6	
Summer. April	+0·8	+0·9	+0·8	+0·7	+0·7	+0·7	+0·9	+0·8	0	−1·0	−2·3	−2·9	−2·8	−1·8	−0·8	0	+0·4	+0·4	+0·4	+0·4	+0·5	+0·6	+0·7	+0·8	+0·7	
May	+0·5	+0·4	+0·5	+0·4	+0·5	+0·4	+0·7	+0·5	−0·1	−1·0	−1·7	−2·0	−1·8	−1·2	−0·6	+0·1	+0·5	+0·5	+0·3	+0·3	+0·3	+0·5	+0·5	+0·6	+0·5	
June	+0·7	+0·6	+0·6	+0·6	+0·5	+0·6	+0·7	+0·4	−0·3	−1·1	−1·7	−1.9	−1·8	−1·3	−0·7	−0·1	+0·4	+0·7	+0·6	+0·5	+0·6	+0·7	+0·7	+0·6	+0·6	
July	+0·6	+0·6	+0·5	+0·5	+0·6	+0·6	+0·9	+0·5	−0·3	−1·1	−1·8	−2·0	−1·8	−1·4	−0·8	−0·3	+0·4	+0·6	+0·6	+0·4	+0·5	+0·6	+0·6	+0·6	+0·6	
Aug.	+0·6	+0·7	+0·6	+0·6	+0·5	+0·7	+1·0	+0·7	−0·2	−1·2	−1·7	−2·0	−2·0	−1·6	−0·9	−0·3	+0·3	+0·6	+0·5	+0·4	+0·5	+0·6	+0·6	+0·7	+0·7	
Sep.	+0·7	+0·7	+0·7	+0·6	+0·6	+0·6	+1·0	+0·9	0	−1·4	−2·3	−2·6	−2·5	−1·6	−0·6	+0·2	+0·5	+0·4	+0·4	+0·6	+0·7	+0·8	+0·8	+0·8	+0·8	
Means	+0·6	+0·6	+0·6	+0·5	+0·5	+0·6	+0·8	+0·6	−0·2	−1·2	−1·9	−2·3	−2·1	−1·5	−0·8	−0·1	+0·4	+0·5	+0·4	+0·4	+0·5	+0·6	+0·6	+0·7	+0·6	

Note.—When the sign is + the Dip is greater, and when − it is less than the mean.

Digitized by Google

F.—*Hourly Means of the Declination at Kodaikanal in 1915, determined from all available days. Declination = W. 1° + tabular quantity.*

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	19′·6	19′·7	19′·7	19′·8	20′·0	20′·2	20′·4	20′·7	20′·2	19′·5	19′·7	20′·1	20′·1	19′·6	19′·3	19′·2	19′·3	19′·5	19′·7	19′·5	19′·6	19′·6	19′·6	19′·7	19′·7	19′·8
Winter. Feb.	20·2	20·2	20·2	20·2	20·3	20·4	20·3	20·3	20·3	20·6	21·1	21·6	21·4	20·8	20·0	19·6	19·4	19·7	20·0	20·0	20·1	20·2	20·2	20·2	20·3	20·3
Winter. Mar.	20·5	20·5	20·5	20·6	20·7	20·8	20·8	20·5	20·2	20·1	20·3	20·8	21·4	21·8	21·5	20·8	20·2	20·2	20·4	20·6	20·7	20·6	20·6	20·5	20·5	20·6
Winter. Oct.	23·8	23·7	23·8	23·8	23·9	24·0	23·8	23·3	23·2	23·5	24·0	24·8	24·8	24·4	23·8	23·3	23·1	23·4	23·6	23·7	23·9	23·9	24·0	23·9	23·8	23·8
Winter. Nov.	24·0	24·1	24·1	24·1	24·3	24·5	24·4	24·4	24·3	24·4	24·9	25·2	24·9	24·1	23·7	23·4	23·5	23·8	23·8	23·8	24·0	24·1	24·3	24·2	24·1	24·2
Winter. Dec.	25·0	25·0	25·1	25·1	25·2	25·3	25·3	25·3	25·1	24·8	25·0	25·5	25·5	25·1	24·9	24·7	24·5	24·6	24·7	24·6	24·7	24·8	24·9	25·0	25·0	25·0
Means	22·2	22·2	22·2	22·3	22·4	22·5	22·5	22·4	22·2	22·2	22·5	23·0	23·0	22·6	22·2	21·8	21·7	21·9	22·0	22·0	22·2	22·2	22·3	22·3	22·2	22·3
Summer. April	20·8	20·7	20·6	20·7	20·8	20·8	20·4	19·9	19·9	20·1	20·7	21·7	22·7	22·9	22·3	21·4	20·7	20·6	20·8	21·2	21·3	21·2	21·1	20·9	20·8	21·0
Summer. May	21·4	21·3	21·3	21·3	21·3	21·2	20·5	20·1	20·3	21·1	22·2	23·0	23·8	23·2	22·6	21·9	21·3	21·2	21·4	21·9	22·0	22·0	21·8	21·6	21·4	21·6
Summer. June	22·1	22·0	21·9	21·8	21·9	21·8	21·1	20·8	20·3	21·1	22·2	23·1	23·8	23·9	23·4	22·9	22·3	22·0	22·0	22·3	22·5	22·4	22·4	22·3	22·1	22·2
Summer. July	22·6	22·5	22·4	22·4	22·3	22·2	21·5	20·5	20·6	21·5	22·5	23·7	24·5	24·6	24·1	23·4	22·8	22·3	22·3	22·6	22·9	22·9	22·8	22·8	22·6	22·6
Summer. Aug.	23·2	23·0	22·9	22·9	22·7	22·5	21·8	20·8	21·0	22·1	23·3	24·3	24·9	24·8	24·2	23·5	22·8	22·6	22·6	23·0	23·2	23·3	23·3	23·3	23·2	23·0
Summer. Sep.	23·4	23·4	23·3	23·3	23·2	23·1	22·1	21·2	21·5	22·7	23·8	24·8	25·5	25·4	24·6	23·4	22·9	22·8	23·0	23·4	23·5	23·5	23·5	23·5	23·4	23·4
Means	22·3	22·2	22·1	22·1	22·0	21·9	21·2	20·5	20·6	21·4	22·5	23·4	24·1	24·1	23·5	22·8	22·1	21·9	22·0	22·4	22·6	22·6	22·5	22·4	22·3	22·3

Diurnal Inequality of the Declination at Kodaikanal in 1915, deduced from the above Table.

Winter. Jan.	+0′·2	+0′·1	+0′·1	0′	−0′·2	−0′·4	−0′·6	−0′·9	−0′·4	+0′·3	+0′·1	−0′·3	−0′·3	+0′·2	+0′·5	+0′·6	+0′·5	+0′·3	+0′·1	+0′·3	+0′·2	+0′·2	+0′·2	+0′·1	+0′·1	
Winter. Feb.	+0·1	+0·1	+0·1	+0·1	0	−0·1	0	0	0	−0·3	−0·8	−1·3	−1·1	−0·5	+0·3	+0·7	+0·9	+0·6	+0·3	+0·3	+0·2	+0·1	+0·1	+0·1	0	
Winter. Mar.	+0·1	+0·1	+0·1	0	−0·1	−0·2	−0·2	+0·1	+0·4	+0·5	+0·3	−0·2	−0·8	−1·2	−0·9	−0·2	+0·4	+0·4	+0·2	0	−0·1	0	0	+0·1	+0·1	
Winter. Oct.	0	+0·1	0	0	−0·1	−0·2	0	+0·5	+0·6	+0·3	−0·2	−1·0	−1·0	−0·6	0	+0·5	+0·7	+0·4	+0·2	+0·1	−0·1	−0·1	−0·2	−0·1	0	
Winter. Nov.	+0·2	+0·1	+0·1	+0·1	−0·1	−0·3	−0·2	−0·2	−0·1	−0·2	−0·7	−1·0	−0·7	+0·1	+0·5	+0·8	+0·7	+0·4	+0·4	+0·4	+0·2	+0·1	−0·1	0	+0·1	
Winter. Dec.	0	0	−0·1	−0·1	−0·2	−0·3	−0·3	−0·3	−0·1	+0·2	0	−0·5	−0·5	−0·1	+0·1	+0·3	+0·5	+0·4	+0·3	+0·4	+0·3	+0·2	+0·1	0	0	
Means	+0·1	+0·1	+0·1	0	−0·1	−0·2	−0·2	−0·1	+0·1	+0·1	−0·2	−0·7	−0·7	−0·3	+0·1	+0·5	+0·6	+0·4	+0·3	+0·3	+0·1	+0·1	0	0	+0·1	
Summer. April	+0·2	+0·3	+0·4	+0·3	+0·2	+0·2	+0·6	+1·1	+1·1	+0·9	+0·3	−0·7	−1·7	−1·9	−1·3	−0·4	+0·3	+0·4	+0·2	−0·2	−0·3	−0·2	−0·1	+0·1	+0·2	
Summer. May	+0·2	+0·3	+0·3	+0·3	+0·3	+0·4	+1·1	+1·5	+1·3	+0·5	−0·6	−1·4	−1·7	−1·6	−1·0	−0·3	+0·3	+0·4	+0·2	−0·3	−0·4	−0·4	−0·2	0	+0·2	
Summer. June	+0·1	+0·2	+0·3	+0·4	+0·3	+0·4	+1·1	+1·9	+1·9	+1·1	0	−0·9	−1·6	−1·7	−1·2	−0·7	−0·1	+0·2	+0·2	−0·1	−0·3	−0·2	−0·2	−0·1	+0·1	
Summer. July	0	+0·1	+0·2	+0·2	+0·3	+0·4	+1·1	+2·1	+2·0	+1·1	+0·1	−1·1	−1·9	−2·0	−1·5	−0·8	−0·2	+0·3	+0·3	0	−0·3	−0·3	−0·2	−0·2	0	
Summer. Aug.	−0·2	0	+0·1	+0·1	+0·3	+0·5	+1·2	+2·2	+2·0	+0·9	−0·3	−1·3	−1·9	−1·8	−1·2	−0·5	+0·2	+0·4	+0·4	0	−0·2	−0·3	−0·3	−0·3	−0·2	
Summer. Sep.	0	0	+0·1	+0·1	+0·2	+0·3	+1·3	+2·2	+1·9	+0·7	−0·4	−1·4	−2·1	−2·0	−1·2	0	+0·5	+0·6	+0·4	0	−0·1	−0·1	−0·1	−0·1	0	
Means	0	+0·1	+0·2	+0·2	+0·3	+0·4	+1·1	+1·8	+1·7	+0·9	−0·2	−1·1	−1·8	−1·8	−1·2	−0·5	+0·2	+0·4	+0·3	−0·1	−0·3	−0·3	−0·2	−0·1	0	

NOTE.—When the sign is + the magnet points to the East, and when − to the West of the mean position.

Digitized by Google

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Kodaikanal in 1915, from all available days. Horizontal Force = ·37000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	594	595	596	597	597	597	599	606	618	641	657	**662**	651	628	607	598	596	597	597	595	594	592	**592**	593	594	608
	Feb.	587	588	591	592	592	593	594	599	615	636	653	**658**	650	631	616	602	600	599	596	591	589	587	588	**586**	587	606
	Mar.	591	590	592	596	595	595	594	599	616	643	666	**675**	666	646	627	611	603	600	596	593	592	590	591	**587**	591	611
	Oct.	600	599	601	602	603	602	601	606	629	660	681	**685**	673	655	636	622	616	612	606	602	599	**596**	596	598	600	620
	Nov.	**590**	595	597	597	597	596	596	604	623	641	**655**	653	635	620	608	606	606	606	601	599	596	596	597	597	597	609
	Dec.	**604**	605	606	608	609	608	607	611	623	642	660	**670**	663	645	630	621	617	616	611	608	607	605	606	605	607	620
	Means	**594**	595	597	599	599	599	599	604	621	644	662	**667**	656	638	621	610	606	605	601	598	596	594	595	594	596	612
Summer.	April	592	595	596	596	597	598	597	605	629	662	687	**695**	681	656	625	608	603	605	604	599	596	594	593	**591**	593	617
	May	602	601	604	604	605	604	606	611	631	654	670	**673**	660	643	623	610	605	605	606	604	602	601	**601**	601	602	618
	June	595	597	597	598	597	597	600	605	617	633	651	**659**	659	643	626	611	598	593	592	592	**592**	593	593	595	597	610
	July	595	596	597	597	596	597	600	605	615	635	649	**655**	650	641	627	614	601	595	594	595	594	**594**	594	595	595	610
	Aug.	600	603	604	603	603	603	605	610	627	648	662	**672**	669	656	641	624	612	605	606	603	600	600	**599**	600	600	619
	Sep.	603	604	606	608	608	607	607	614	637	669	691	**697**	683	660	633	615	607	607	607	602	598	**597**	598	600	602	623
	Means	598	599	601	601	601	601	603	608	626	650	668	**675**	667	650	629	614	604	602	602	599	597	597	**596**	597	598	616

Diurnal Inequality of the Horizontal Force at Kodaikanal in 1915, deduced from the above Table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter.	Jan.	− 14	− 13	− 12	− 11	− 11	− 11	− 9	− 2	+ 10	+ 33	+ 49	+ **54**	+ 43	+ 20	− 1	− 10	− 12	− 11	− 11	− 13	− 14	− 16	− **16**	− 15	− 14	
	Feb.	− 19	− 18	− 15	− 14	− 14	− 13	− 12	− 7	+ 9	+ 30	+ 47	+ **52**	+ 44	+ 25	+ 10	− 4	− 6	− 7	− 10	− 15	− 17	− 19	− 18	− **20**	− 19	
	Mar.	− 20	− 21	− 19	− 15	− 16	− 16	− 17	− 12	+ 5	+ 32	+ 55	+ **64**	+ 55	+ 35	+ 16	0	− 8	− 11	− 15	− 18	− 19	− 21	− 20	− **24**	− 20	
	Oct.	− 20	− 21	− 19	− 18	− 17	− 18	− 19	− 14	+ 9	+ 40	+ 61	+ **65**	+ 53	+ 35	+ 16	+ 2	− 4	− 8	− 14	− 18	− 21	− **24**	− 24	− 22	− 20	
	Nov.	− **19**	− 14	− 12	− 12	− 12	− 13	− 13	− 5	+ 14	+ 32	+ **46**	+ 44	+ 26	+ 11	− 1	− 3	− 3	− 3	− 8	− 10	− 13	− 13	− 12	− 12	− 12	
	Dec.	− **16**	− 15	− 14	− 12	− 11	− 12	− 13	− 9	+ 3	+ 22	+ 40	+ **50**	+ 43	+ 25	+ 10	+ 1	− 3	− 4	− 9	− 12	− 13	− 15	− 14	− 15	− 13	
	Means	− **18**	− 17	− 15	− 13	− 13	− 13	− 13	− 8	+ 9	+ 32	+ 50	+ **55**	+ 44	+ 26	+ 9	− 2	− 6	− 7	− 11	− 14	− 16	− 18	− 17	− 18	− 16	
Summer.	April	− 25	− 22	− 21	− 21	− 20	− 19	− 20	− 12	+ 12	+ 45	+ 70	+ **78**	+ 64	+ 39	+ 8	− 9	− 14	− 12	− 13	− 18	− 21	− 23	− 24	− **26**	− 24	
	May	− 16	− 17	− 14	− 14	− 13	− 14	− 12	− 7	+ 13	+ 36	+ 52	+ **55**	+ 42	+ 25	+ 5	− 8	− 13	− 13	− 12	− 14	− 16	− 17	− **17**	− 17	− 16	
	June	− 15	− 13	− 13	− 12	− 13	− 13	− 10	− 5	+ 7	+ 23	+ 41	+ **49**	+ 49	+ 33	+ 16	+ 1	− 12	− 17	− 18	− 18	− **18**	− 17	− 17	− 15	− 13	
	July	− 15	− 14	− 13	− 13	− 14	− 13	− 10	− 5	+ 5	+ 25	+ 39	+ **45**	+ 40	+ 31	+ 17	+ 4	− 9	− 15	− 16	− 15	− 16	− **16**	− 16	− 15	− 15	
	Aug.	− 19	− 16	− 15	− 16	− 16	− 16	− 14	− 9	+ 8	+ 29	+ 43	+ **53**	+ 50	+ 37	+ 22	+ 5	− 7	− 14	− 13	− 16	− 19	− 19	− **20**	− 19	− 19	
	Sep.	− 20	− 19	− 17	− 15	− 15	− 16	− 16	− 9	+ 14	+ 46	+ 68	+ **74**	+ 60	+ 37	+ 10	− 8	− 16	− 16	− 16	− 21	− 25	− **26**	− 25	− 23	− 21	
	Means	− 18	− 17	− 15	− 15	− 15	− 15	− 13	− 8	+ 10	+ 34	+ 52	+ **59**	+ 51	+ 34	+ 13	− 2	− 12	− 14	− 14	− 17	− 19	− 19	− **20**	− 19	− 18	

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Kodaikanal in 1915, from all available days. Vertical Force = ·02000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	785	786	785	786	785	786	786	**786**	785	781	773	767	**765**	767	773	779	780	779	781	782	783	783	784	785	786	781
	Feb.	799	799	**800**	800	800	800	800	798	793	787	783	**780**	783	788	793	794	792	790	793	795	796	796	798	798	800	794
	Mar.	811	810	811	812	810	811	**812**	812	809	804	798	788	**786**	788	790	796	800	802	803	806	807	808	809	810	812	804
	Oct.	837	835	836	836	835	836	**839**	837	833	826	820	**814**	816	818	821	823	824	825	828	830	830	832	833	835	837	829
	Nov.	845	846	846	845	845	845	**847**	844	840	834	**832**	833	837	840	841	840	837	837	840	840	841	842	844	844	844	841
	Dec	846	847	847	847	848	847	**849**	847	844	837	830	826	**825**	827	830	836	839	839	841	843	844	844	846	846	847	841
	Means	821	821	821	821	821	821	**822**	821	817	812	806	**801**	802	805	808	811	812	812	814	816	817	818	819	820	821	815
Summer.	April	814	815	814	814	814	815	**818**	816	809	801	793	782	**777**	782	793	803	808	807	806	807	808	811	812	813	814	805
	May	818	818	819	818	819	820	**823**	822	816	808	803	**799**	799	803	809	813	816	816	814	813	814	816	817	818	818	814
	June	823	823	823	823	822	824	827	**828**	824	817	811	806	**804**	808	812	815	817	819	818	818	819	820	821	822	823	818
	July	829	829	830	830	829	831	**835**	834	830	823	818	**817**	818	820	823	827	827	827	826	825	825	827	828	829	829	827
	Aug.	828	829	828	828	828	830	**834**	830	820	811	805	**802**	802	806	809	813	818	820	821	821	822	824	825	827	828	820
	Sep.	838	838	839	839	839	840	**843**	837	824	814	806	**799**	799	807	816	825	830	828	828	829	831	834	835	837	838	827
	Means	825	825	826	825	825	827	**830**	828	821	812	806	801	**800**	804	810	816	819	820	819	819	820	822	823	824	825	819

Diurnal Inequality of the Vertical Force at Kodaikanal in 1915, deduced from the above Table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter.	Jan.	+ 4	+ 5	+ 4	+ 5	+ 4	+ 5	+ 5	+ 5	+ 4	0	− 8	− 14	− 16	− 14	− 8	− 2	− 1	− 2	0	+ 1	+ 2	+ 2	+ 3	+ 4	+ 5	
	Feb.	+ 5	+ 5	+ 6	+ 6	+ 6	+ 6	+ 6	+ 4	− 1	− 7	− 11	− 14	− 11	− 6	− 1	0	− 2	− 4	− 1	+ 1	+ 2	+ 2	+ 4	+ 4	+ 6	
	Mar.	+ 7	+ 6	+ 7	+ 8	+ 6	+ 7	+ 8	+ 8	+ 5	0	− 6	− 16	− 18	− 16	− 14	− 8	− 4	− 2	− 1	+ 2	+ 3	+ 4	+ 5	+ 6	+ 8	
	Oct.	+ 8	+ 6	+ 7	+ 7	+ 6	+ 7	+ 10	+ 8	+ 4	− 3	− 9	− 15	− 13	− 11	− 8	− 6	− 5	− 4	− 1	+ 1	+ 1	+ 3	+ 4	+ 6	+ 8	
	Nov.	+ 4	+ 5	+ 5	+ 4	+ 4	+ 4	+ 6	+ 3	− 1	− 7	− 9	− 8	− 4	− 1	0	− 1	− 4	− 4	− 1	− 1	0	+ 1	+ 3	+ 3	+ 3	
	Dec.	+ 5	+ 6	+ 6	+ 6	+ 7	+ 6	+ 8	+ 6	+ 3	− 4	− 11	− 15	− 16	− 14	− 11	− 5	− 2	− 2	0	+ 2	+ 3	+ 3	+ 5	+ 5	+ 6	
	Means	+ 6	+ 6	+ 6	+ 6	+ 6	+ 6	+ 7	+ 6	+ 2	− 3	− 9	− 14	− 13	− 10	− 7	− 4	− 3	− 3	− 1	+ 1	+ 2	+ 3	+ 4	+ 5	+ 6	
Summer.	April	+ 9	+ 10	+ 9	+ 9	+ 9	+ 10	+ 13	+ 11	+ 4	− 4	− 12	− 23	− 28	− 23	− 12	− 2	+ 3	+ 2	+ 1	+ 2	+ 3	+ 6	+ 7	+ 8	+ 9	
	May	+ 4	+ 4	+ 5	+ 4	+ 5	+ 6	+ 9	+ 8	+ 2	− 6	− 11	− 15	− 15	− 11	− 5	− 1	+ 2	+ 2	0	− 1	0	+ 2	+ 3	+ 4	+ 4	
	June	+ 5	+ 5	+ 5	+ 5	+ 4	+ 6	+ 9	+ 10	+ 6	− 1	− 7	− 12	− 14	− 10	− 6	− 3	− 1	+ 1	0	0	+ 1	+ 2	+ 3	+ 4	+ 5	
	July	+ 2	+ 2	+ 3	+ 3	+ 2	+ 4	+ 8	+ 7	+ 3	− 4	− 9	− 10	− 9	− 7	− 4	0	0	0	− 1	− 2	− 2	0	+ 1	+ 2	+ 2	
	Aug.	+ 8	+ 9	+ 8	+ 8	+ 8	+ 10	+ 14	+ 10	0	− 9	− 15	− 18	− 18	− 14	− 11	− 7	− 2	0	+ 1	+ 1	+ 2	+ 4	+ 5	+ 7	+ 8	
	Sep.	+ 11	+ 11	+ 12	+ 12	+ 12	+ 13	+ 16	+ 10	− 3	− 13	− 21	− 28	− 28	− 20	− 11	− 2	+ 3	+ 1	+ 1	+ 2	+ 4	+ 7	+ 8	+ 10	+ 11	
	Means	+ 6	+ 6	+ 7	+ 6	+ 6	+ 8	+ 11	+ 9	+ 2	− 7	− 13	− 18	− 19	− 15	− 9	− 3	0	+ 1	0	0	+ 1	+ 3	+ 4	+ 5	+ 6	

NOTE:—When the sign is + the V.F. is greater, and when − it is less than the mean.

Digitized by Google

Hourly Means of the Dip at Kodaikanal in 1915, determined from all available days. Dip = N. 4° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	14′·2	14′·3	14′·2	14′·3	14′·2	14′·3	14′·3	14′·2	14′·1	13′·5	12′·7	12′·1	12′·0	12′·4	13′·0	13′·6	13′·7	13′·7	13′·8	13′·9	14′·0	14′·0	14′·1	14′·2	14′·3	13′·7
Feb.	15·5	15·5	15·6	15·6	15·6	15·6	15·6	15·4	14·8	14·1	13·6	13·3	13·7	14·2	14·8	15·0	14·8	14·6	14·9	15·1	15·3	15·3	15·4	15·5	15·6	15·0
Mar.	16·6	16·5	16·6	16·7	16·5	16·6	16·7	16·6	16·2	15·6	14·9	13·9	13·8	14·1	14·4	15·1	15·5	15·7	15·8	16·1	16·2	16·3	16·4	16·5	16·7	15·8
Oct.	18·9	18·7	18·8	18·8	18·7	18·8	19·1	18·9	18·3	17·5	16·8	16·2	16·5	16·8	17·2	17·5	17·6	17·7	18·0	18·3	18·3	18·5	18·6	18·7	18·9	18·1
Nov.	19·7	19·8	19·7	19·7	19·7	19·7	19·8	19·5	19·0	18·4	18·1	18·2	18·7	19·0	19·2	19·1	18·9	18·9	19·2	19·2	19·3	19·4	19·6	19·6	19·6	19·2
Dec.	19·7	19·8	19·8	19·8	19·8	19·8	19·9	19·7	19·4	18·6	17·9	17·4	17·4	17·7	18·1	18·7	19·0	19·0	19·2	19·4	19·5	19·5	19·7	19·7	19·8	19·1
Means	17·4	17·4	17·5	17·5	17·4	17·5	17·6	17·4	17·0	16·3	15·7	15·2	15·4	15·7	16·1	16·5	16·6	16·6	16·8	17·0	17·1	17·2	17·3	17·4	17·5	16·8
Summer. April	16·9	16·9	16·8	16·8	16·8	16·9	17·2	17·0	16·2	15·2	14·3	13·3	12·9	13·5	14·7	15·8	16·2	16·1	16·1	16·2	16·3	16·6	16·7	16·8	16·9	15·9
May	17·2	17·2	17·2	17·2	17·2	17·3	17·6	17·5	16·8	15·9	15·3	15·0	15·0	15·5	16·2	16·7	17·0	17·0	16·8	16·7	16·8	17·0	17·1	17·2	17·2	16·7
June	17·7	17·7	17·7	17·6	17·6	17·7	18·0	18·0	17·6	16·9	16·2	15·7	15·5	16·0	16·5	16·8	17·1	17·3	17·2	17·2	17·3	17·4	17·5	17·6	17·7	17·2
July	18·2	18·2	18·3	18·3	18·2	18·4	18·7	18·6	18·2	17·4	16·8	16·7	16·8	17·1	17·4	17·9	18·0	18·0	17·9	17·8	17·9	18·0	18·1	18·2	18·2	17·9
Aug.	18·1	18·2	18·1	18·1	18·1	18·2	18·6	18·2	17·2	16·2	15·6	15·2	15·3	15·7	16·1	16·6	17·1	17·3	17·4	17·4	17·5	17·7	17·8	18·0	18·1	17·2
Sep.	19·0	19·0	19·0	19·0	19·0	19·1	19·4	18·8	17·5	16·3	15·5	14·8	14·9	15·8	16·8	17·7	18·2	18·0	18·0	18·2	18·4	18·7	18·7	18·9	19·0	17·9
Means	17·9	17·9	17·9	17·8	17·8	17·9	18·3	18·0	17·3	16·3	15·6	15·1	15·1	15·6	16·3	16·9	17·3	17·3	17·2	17·3	17·4	17·6	17·7	17·8	17·9	17·1

Diurnal Inequality of the Dip at Kodaikanal in 1915, deduced from the above Table.

Winter. Jan.	+ 0′·5	+ 0′·6	+ 0′·5	+ 0′·6	+ 0′·5	+ 0′·6	+ 0′·6	+ 0′·5	+ 0′·4	− 0′·2	− 1′·0	− 1′·6	− 1′·7	− 1′·3	− 0′·7	− 0′·1	0′	0′	+ 0′·1	+ 0′·2	+ 0′·3	+ 0′·3	+ 0′·4	+ 0′·5	+ 0′·6	
Feb.	+ 0·5	+ 0·5	+ 0·6	+ 0·6	+ 0·6	+ 0·6	+ 0·6	+ 0·4	− 0·2	− 0·9	− 1·4	− 1·7	− 1·3	− 0·8	− 0·2	0	− 0·2	− 0·4	− 0·1	+ 0·1	+ 0·3	+ 0·3	+ 0·4	+ 0·5	+ 0·6	
Mar.	+ 0·8	+ 0·7	+ 0·8	+ 0·9	+ 0·7	+ 0·8	+ 0·9	+ 0·8	+ 0·4	− 0·2	− 0·9	− 1·9	− 2·0	− 1·7	− 1·4	− 0·7	− 0·3	− 0·1	0	+ 0·3	+ 0·4	+ 0·5	+ 0·6	+ 0·7	+ 0·9	
Oct.	+ 0·8	+ 0·6	+ 0·7	+ 0·7	+ 0·6	+ 0·7	+ 1·0	+ 0·8	+ 0·2	− 0·6	− 1·3	− 1·9	− 1·6	− 1·3	− 0·9	− 0·6	− 0·5	− 0·4	− 0·1	+ 0·2	+ 0·2	+ 0·4	+ 0·5	+ 0·6	+ 0·8	
Nov.	+ 0·5	+ 0·6	+ 0·5	+ 0·5	+ 0·5	+ 0·5	+ 0·6	+ 0·3	− 0·2	− 0·8	− 1·1	− 1·0	− 0·5	− 0·2	0	− 0·1	− 0·3	− 0·3	0	0	+ 0·1	+ 0·2	+ 0·4	+ 0·4	+ 0·4	
Dec.	+ 0·6	+ 0·7	+ 0·7	+ 0·7	+ 0·7	+ 0·7	+ 0·8	+ 0·6	+ 0·3	− 0·5	− 1·2	− 1·7	− 1·7	− 1·4	− 1·0	− 0·4	− 0·1	− 0·1	+ 0·1	+ 0·3	+ 0·4	+ 0·4	+ 0·6	+ 0·6	+ 0·7	
Means	+ 0·6	+ 0·6	+ 0·7	+ 0·7	+ 0·6	+ 0·7	+ 0·8	+ 0·6	+ 0·2	− 0·5	− 1·1	− 1·6	− 1·4	− 1·1	− 0·7	− 0·3	− 0·2	− 0·2	0	+ 0·2	+ 0·3	+ 0·4	+ 0·5	+ 0·6	+ 0·7	
Summer. April	+ 1·0	+ 1·0	+ 0·9	+ 0·9	+ 0·9	+ 1·0	+ 1·3	+ 1·1	+ 0·3	− 0·7	− 1·6	− 2·6	− 3·0	− 2·4	− 1·2	− 0·1	+ 0·3	+ 0·2	+ 0·2	+ 0·3	+ 0·4	+ 0·7	+ 0·8	+ 0·9	+ 1·0	
May	+ 0·5	+ 0·5	+ 0·5	+ 0·5	+ 0·5	+ 0·6	+ 0·9	+ 0·8	+ 0·1	− 0·8	− 1·4	− 1·7	− 1·7	− 1·2	− 0·5	0	+ 0·3	+ 0·3	+ 0·1	0	+ 0·1	+ 0·3	+ 0·4	+ 0·5	+ 0·5	
June	+ 0·5	+ 0·5	+ 0·5	+ 0·4	+ 0·4	+ 0·5	+ 0·8	+ 0·8	+ 0·4	− 0·3	− 1·0	− 1·5	− 1·7	− 1·2	− 0·7	− 0·4	− 0·1	+ 0·1	0	0	+ 0·1	+ 0·2	+ 0·3	+ 0·4	+ 0·5	
July	+ 0·3	+ 0·3	+ 0·4	+ 0·4	+ 0·3	+ 0·5	+ 0·8	+ 0·7	+ 0·3	− 0·5	− 1·1	− 1·2	− 1·1	− 0·8	− 0·5	0	+ 0·1	+ 0·1	0	− 0·1	0	+ 0·1	+ 0·2	+ 0·3	+ 0·3	
Aug.	+ 0·9	+ 1·0	+ 0·9	+ 0·9	+ 0·9	+ 1·0	+ 1·4	+ 1·0	0	− 1·0	− 1·6	− 2·0	− 1·9	− 1·5	− 1·1	− 0·6	− 0·1	+ 0·1	+ 0·2	+ 0·2	+ 0·3	+ 0·5	+ 0·6	+ 0·8	+ 0·9	
Sep.	+ 1·1	+ 1·1	+ 1·1	+ 1·1	+ 1·1	+ 1·2	+ 1·5	+ 0·9	− 0·4	− 1·6	− 2·4	− 3·1	− 3·0	− 2·1	− 1·1	− 0·2	+ 0·3	+ 0·1	+ 0·1	+ 0·3	+ 0·5	+ 0·8	+ 0·8	+ 1·0	+ 1·1	
Means	+ 0·8	+ 0·8	+ 0·8	+ 0·7	+ 0·7	+ 0·8	+ 1·2	+ 0·9	+ 0·2	− 0·8	− 1·5	− 2·0	− 2·0	− 1·5	− 0·8	− 0·2	+ 0·2	+ 0·2	+ 0·1	+ 0·2	+ 0·3	+ 0·5	+ 0·6	+ 0·7	+ 0·8	

Note.—When the sign is + the Dip is greater, and when − it is less than the mean.

Digitized by Google

No. 19 PARTY (BASE LINE).

By E. C. J. Bond.

PERSONNEL.

Provincial Officers.

Khan Bahadur Syed Aulad Hossein from 1st October 1915 to 30th November 1915.

Mr. E. C. J. Bond, in charge from 1st December 1915.

Mr. O. N. Pushong, attached from 1st December 1915.

Lower Subordinate Service.

2 Computers, etc.

Owing to the deficiency of officers in the department, caused by the war, no Base Line work was practicable during the year.

A traverse survey of the Imperial Delhi Area boundary, on the west side of the Jumna river, was undertaken by the party. A report on this work is given in Part III.—Special Report, at the end of this volume.

Programme for 1916-17.—During the ensuing field season triangulation will be carried out in Delhi for providing points to No. 2 party, Northern Circle, for the revision of the 4-inch maps of "Delhi and vicinity", and also for the control of the traverse of the Imperial Delhi Area boundary, on the east side of the Jumna river, to be executed by No. 2 Party.

THE COMPUTING OFFICE.

By J. de Graaff Hunter, M. A.

PERSONNEL.

Imperial Officer.

J. de Graaff Hunter, Esq., M. A., in charge.

Provincial Officer.

Mr Hanuman Prasad, Extra Asstt. Supdt.

Computing Office.

Rai Sahib Ishan Chandra Deva, B. A. and 11 Computers, 4 Computers attached (8 Computers from the field parties worked for a portion of the year in Computing Office) 10 book-binders.

Printing Office.

Mr. Sarat Kumar Mukerji, Sub-Asstt. Supdt. 17 Compositors, 3 Printers.

Workshops.

1 Head Artificer, 8 fitters and carpenters.

The office was visited by H. H. Sir James Meston, K.C.S.I., LL.D., V.D., Lieutenant-Governor on 14th July 1916.

COMPUTING SECTION.

The excellent services of Mr. Ishan Chandra Deva in the Computing Office from 1885 and as Head Computer from 1908 have been recognised, and the title of Rai Sahib has been conferred on him. The Gazette of 3rd June 1916 contained the following announcement:—

"His Excellency the Viceroy and Governor General has been pleased to confer the title of Rai Sahib as a personal distinction upon

Mr. Ishan Chandra Deb, B.A., Head Computer, Trigonometrical Survey Office, Dehra Dun".

On 2nd September 1916 Colonel G. P. Lenox Conyngham, R.E., Superintendent of the Trigonometrical Survey held a public durbar and handed the *sanad* of Rai Sahib to Mr. Ishan Chandra Deva.

A "Millionaire", an arithmometer of greatly improved pattern, a Comptometer (adding machine) and 7 slide rules have been received in the Computing Office during the year. The addition of these instruments has greatly facilitated the work of computations.

Triangulation Pamphlets. Good progress has been made with the compilation of "G. T. data" (*i.e.* all data available in the Head Quarters office, Dehra) for triangulation pamphlets. The Computing Office in conjunction with 15 Party have compiled data for 205 degree sheets during the 12 months under review. Certain minor alterations have been introduced, but in the main the procedure explained in last year's report has been found satisfactory in practice.

Adjustment of triangulation. The revisionary triangulation at the junction of the Burma Coast Series and the Manipur Meridional Series was completed in February by 15 Party and the observations were shortly afterwards reduced. It was not possible to take up the adjustment of the Burma triangulation at once, but a start has now been made and the solution of the necessary equations for the adjustment is nearly completed. It is hoped that the adjustment will be completed in 1916 but it has only been possible up to the present to apply two computers to the work. When this has been completed it will be possible to proceed with Burma triangulation pamphlets.

Digitized by Google

All geodetic triangulation throughout India other than what depends on the Burma triangulation has now been adjusted, the following series having been dealt with during the year:—Sambalpur Meridional (No. 85), Ranchi (No. 83), Ashta (No. 88), Naldrug (No. 90) and Middle Godaveri (No. 92) Series.

Levelling. The dynamic and orthometric values of the following lines of levelling were computed during the year:—

(1) Indian lines. Dacca to Mymensingh; Tindhāria to Darjeeling; Raichur to Bāgalkot; Bareilly to Hāthras; Bareilly to Meerut (revised); Ambāla to Meerut (revised); Sargodha to Multān and Mahiwala; Solon to Simla; Ferozepore to Lahore (revised); Multān to Bahāwalpur; Jacobābād to Quetta; Bellary to Gooty (revised).

(2) Burma lines. Thazi to Mandalay (revised); Mandalay to Myitkyina (revised); Amherst to Pegu; Henzada to Bassein; Thazi to Taunggyi; Minbu to Paugma and Paugma to Salin.

The revision of the levelling line 61 between Meerut and Ambala having thrown doubt on the reliability of the bench-mark at Ambāla Church ($^{B.\ M.\ 2}_{53\ B}$) (*vide* page 77, Records of the Survey of India, Volume VII) its value was computed from Meerut by two different routes, namely *via* Sahāranpur and *via* Delhi and Karnāl. The former gave its value as 900·503 (dynamic), the latter, as 900·581. The mean of these two (*viz.* 900·542) has been adopted as the final value of the bench-mark in supersession of the value published on page 287 of G. T. S. Volume XIX B, and all heights dependent on this have been corrected.

The adjustment of the Assam-Bengal circuit from Pārbatipur *via* Gauhāti, Karīmganj, Akhaura, Dacca and Pachuria to Poradaha has been completed and the results published in addenda to levelling pamphlets 78 and 79.

As mentioned in last year's report, Elephant Point which had hitherto been the datum of level for Burma was considered ill suited to the purpose, seeing that the tidal observatory is 2 miles up the Rangoon river. Mean sea-level as determined by the Amherst Tide-gauge is more reliable and has been adopted as the new datum, and all heights dependent on Elephant Point have been converted to the new terms. The entire Burma levelling previously published with preliminary values has been recomputed. The final dynamic and orthometric values of the unpublished lines have also been worked out. These values will not be modified for many years to come, until probably such time as a junction with the Indian levelling is effected.

A second edition of the Burma pamphlets with orthometric values, is now being printed. This will supersede the old provisional issue of 1911-13. Good progress has already been made in that direction, and pamphlet 94, the first number of the second series, is well advanced through the press.

Press work. During the year press copies for 205 triangulation pamphlets were prepared; this number is exclusive of 20 prepared and printed last year. Proofs of 180 pamphlets were read in the Computing Office and passed.

Addenda to levelling pamphlets 39, 47, 78 and 79, together with the press copy of levelling pamphlet 34 were prepared and proofs passed.

Part I of the 5th Edition of the Auxiliary Tables, comprising 37 Tables of Graticules in 24 pages, was prepared for press and proofs were read and passed.

Proofs of pages 69 to 104 of Professional paper No. 16, at present in the press, were read, examined and passed.

Records. A card index of all the records has been begun and is nearly complete and all the records are now satisfactorily stored in suitable racks.

Research. A complete mechanical analogy to any net-work of series of triangulation has been found, such that the strains in the mechanism correspond to the most probable adjustments in the net-work. The corresponding underlying principles are, in the one the principle of least work, and in the other the principle of minimum squares. This analogy has assisted the consideration of most probable adjustments, and convenient formulæ for the probable closing errors of circuits formed by series of triangulation have been found, which agree satisfactorily with actual results. The probable closing errors in side or azimuth vary as $\sqrt{\Sigma M^2 S}$ where M is the quantity explained in last year's report* and S is the length of the corresponding series in the circuit. The probable closing error in northing or easting depends on the point of closure, and varies as $\sqrt{\int M^2 R^2 ds}$ where R is measured from the closing point. For a line of given form this varies as the three halves power of the linear dimensions.

* Records of the Survey of India, Vol. IX, page 137.

Digitized by Google

The question of probable errors of positions fixed by triangulation after all adjustments have been performed has proved more troublesome, but now appears to have been satisfactorily solved. It is of importance to know how closely a fixing may be relied on, either when comparing with astronomical fixings, or in such cases as when revisionary triangulation is performed to test whether an earthquake has caused appreciable horizontal movement of the ground. The Shillong earthquake of 1897 has been considered from this point of view, and it appears there is not real justification for assuming any wholesale horizontal movement of the ground. To establish such movements more accurate observations would be necessary. The questions briefly alluded to above are being discussed in detail in Professional Paper No. 16 now in the press.

Book binding. During the year a wire stitching machine was received from England and was made use of in stitching the triangulation pamphlets and other small publications, by wire; the machine has been found very useful. The work of binding small pamphlets has thereby been much accelerated.

A good deal of attention has been given to the binding and general appearance of publications, and it has been found possible to make considerable improvements without adding appreciably to the cost of the work.

The following publications and manuscript books were bound:—

Degree triangulation pamphlets	6330	Copies.
Professional Paper No. 15 with gold lettering on back	150	„
Addenda to Levelling pamphlets 43, 47, 78 and 79	800	„
Five Figure Logarithmic Tables	100	„
Auxiliary Tables, 5th Edition, Part I	200	„
Blank angle books for Parties	200	„
Form 17 Topo. (Clinometric Heights) in small books, for Parties ...	1050	„
Old manuscript records of triangulation	450	Books.
Registers for office use	50	Copies.

About 100 books of daily use were also repaired.

Printing Section.

During the year this office has been rearranged and an additional room has been taken over into which the three hand presses have been moved. The main room is now occupied only by compositors and distributers: and all the case-frames have been arranged so as to be more economical of space. Some new case-frames have been received from England and more have now been indented for; so that next year all the old furniture, which is very old and unsatisfactory, will be replaced. A second machine press is expected very shortly and arrangements for its accommodation are being made. These changes have been made necessary by the great increase in printing work which has recently occurred. A larger stock of type has also been received so as to make it possible to give complete proofs of a publication before any part is distributed. This has added to the efficiency of the work.

During the year triangulation pamphlets for 180 degree sheets (G. T. data only) have been printed, totalling 1646 pages. All the graticule tables used in the department (37) have been printed, forming Part I of the 5th edition of the Auxiliary Tables. Professional Paper No. 16 has been printed from pages 69-104.

Workshops.

The Workshops have greatly benefitted from the installation of an electric motor in 1914-15. A sensitive drilling machine has been received during the year 1915-16. The outer lean-to shed has been extended to the full length of the Workshop building and a concrete floor laid down. As the season has been a particularly wet one this has proved invaluable.

A lot of work has been done in the construction of large racks and tables for the various sections and trigonometrical parties. Painting of all the woodwork of the offices has been done by the carpenters. Various minor additions to the office buildings have been made. The need for these was absolutely imperative. Three out of four new masts very similar to that illustrated in Records of the Survey of India, Volume V, page 147 have been made.

The design has been appreciably improved and the mast is now very strong, durable and compact. The wood used is Nana. These masts are for some of the Madura Series (triangulation) station about to be observed at by No. 15 Party.

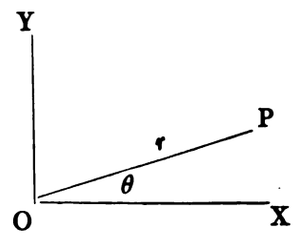
Digitized by Google

Repairs to many instruments and apparatus of the Trigonometrical Parties (notably No. 15 Party) have been carried out. The integrator reported as under construction last year has been satisfactorily finished. It is illustrated in this volume.

Mechanical Integrator for calculating effect of irregularities of form and of density in the earth's crust on the deflection of the plumb-line.—The attraction at O along OP of an elementary cylinder of density ρ of height h and standing on a base of elementary area $rd\,\theta\,dr$ referred to O as origin is $\rho\, rd\,\theta\, dr \frac{h}{r\sqrt{r^2+h^2}}$ or $\frac{\rho h d\, rd\theta}{\sqrt{r^2+h^2}}$.

The components of this in two directions at right angles are

$$\delta X = \frac{\rho h\, dr\, d\theta}{\sqrt{r^2+h^2}} \cos\theta \qquad \delta Y = \frac{\rho h\, dr\, d\theta}{\sqrt{r^2+h^2}} \sin\theta$$



Integrating over a finite area,

$$X = \rho h \int \frac{dr}{\sqrt{r^2+h^2}} \sin\theta \quad Y = -\rho h \int \frac{dr}{\sqrt{r^2+h^2}} \cos\theta$$

These are the integrals then which are sought: except for the case where curvature of the earth has to be taken into account. In this case the expressions may be written

$$X = \rho h \int f(r) \frac{dr}{\sqrt{r^2+h^2}} \sin\theta \quad Y = -\rho h \int f(r) \frac{dr}{\sqrt{r^2+h^2}} \cos\theta$$

and $f(r)$ is a function of r only which is not very different from unity. The form of $f(r)$ will not be considered here as it does not affect the mechanism to any marked extent and the integrator may be arranged to deal with any type of function. The integrator is constructed on the principle of the Kelvin disc-cylinder-sphere integrator, but is arranged to be automatic except so far as it is necessary to follow a pointer round contours of height on a map. If then a plateau of height h and of area defined by any bounding curve on the sea level surface is required, it is necessary to perform the integrations

$$\int \frac{\sin\theta\, dr}{\sqrt{r^2+h^2}} \text{ and } \int \frac{\cos\theta\, dr}{\sqrt{r^2+h^2}}$$

round the bounding curve: and when the attracting mass is at a sufficient distance to make curvature of the earth have appreciable effect, both of these integrals have to be modified by multiplication (under the integral sign) by a function of r which differs little from unity. The integrator performs these integrations as will now be explained.

A is a horizontal disc of 6″ diameter supported at its centre on a point and also on three wheels. These permit A to rotate about a vertical axis through its centre.

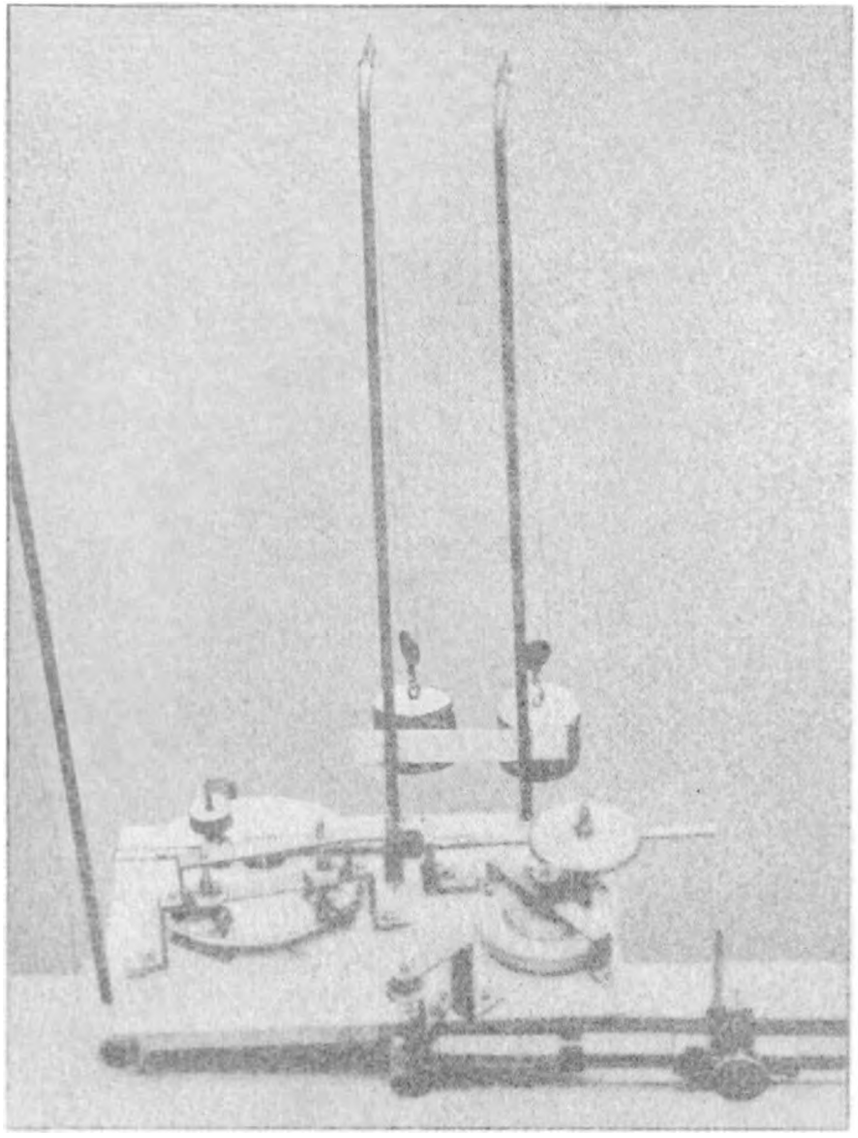
B is a wheel which rubs on the disc. It is free to slide with the shaft CC (the shaft itself does not rotate), but is constrained to rotate on this shaft with the wheel D, to which are attached two rods parallel to the shaft and passing through two holes in B. These can be seen in the photo close to the wheel D.

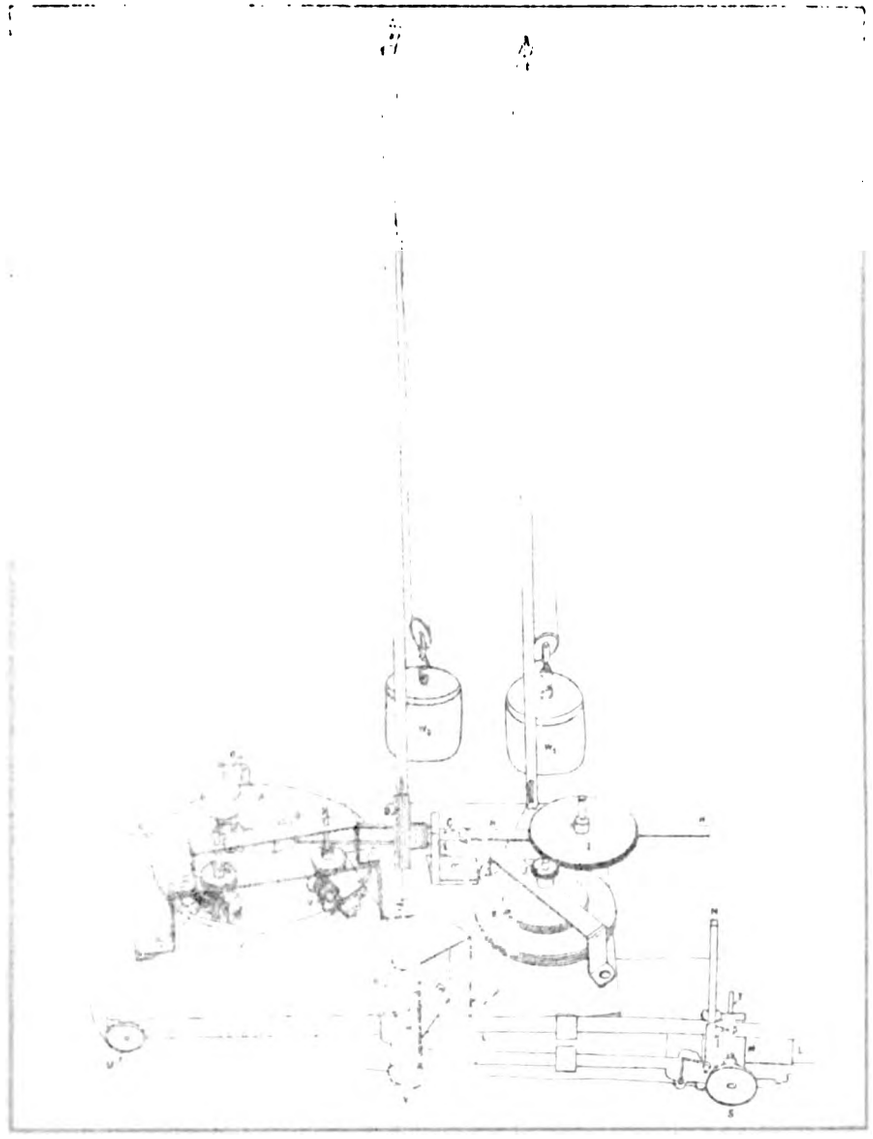
The shaft C fits in a bearing at E which permits of a slight tilting of the shaft in a vertical plane. Behind F is a second bearing carried by an arm pivoted at G on a horizontal axis parallel to the shaft. The reason for this mounting is to enable the wheel B to rise and fall slightly and so to keep a uniform pressure on A in spite of slight lack of truth of A, B, C. The shaft is continued outwards to the right by a rack HH the teeth of which are clear in the photo. The junction of the rack and shaft is made free by pivoting in two directions at right angles to avoid jamming when the shaft rises and falls. The rack passes through a guide below the gear wheel I, and engages another gear wheel clamped on the same shaft with I and below I. Rotation of the wheel I accordingly moves the shaft C and with it the wheel B in direction of the shaft C.

A wire passes from O and is wrapped once round the wheel K and thence goes to the counterweight W_1. A second wire from O passes round the wheel D and thence to the counterweight W_2.

Tracing these wires in the opposite direction they are led from O over little wheels into a vertical direction: and thence over two more wheels outwards along the long arm LL. This arm is pivoted on a vertical axis through O and is also provided with a sliding part MN. The wire which goes to the wheel D is made fast to MN at a height which makes it horizontal along the arm LL: the second wire is attached at a height above the first wire which represents h. If then the arm LL is swung round the axis through O and the portion MN

Digitized by Google





[illegible]

[illegible] Hooper, M.A.

Digitized by Google

Digitized by Google

slid along it so as to follow any boundary line on a chart, it will be seen that the wire to D changes so as to represent dr while the other wire represents $\sqrt{r^2+h^2}$. This second wire is made of suitable length so that when $\sqrt{r^2+h^2}=0$, the wheel B (which is moved along CC proportionally to the movement of the wire and the wheel K) is exactly over the centre of the disc AA. In this way an angular movement proportional to $\frac{dr}{\sqrt{r^2+h^2}}$ is communicated to the disc AA: for the wheel B turns by an amount dr and drives on the disc AA at a distance from its centre proportional to $\sqrt{r^2+h^2}$. The motion of the disc AA is communicated to two counting friction discs P Q (similar to those found in ordinary planimeters) and inclined to the radius of the disc at angles of θ and $90°+\theta$ respectively. These discs accordingly take up the motions

$$\frac{dr}{\sqrt{r^2+h^2}}\cos\theta \quad \text{and} \quad \frac{dr}{\sqrt{r^2+h^2}}\sin\theta$$

respectively. To arrange for their taking up the correct angular positions they are mounted on vertical spindles each bearing a wheel whose periphery is screw cut. A wheel R of the same size and design is mounted on the vertical axis of rotation of the arm LL, and an endless wire passes round these three wheels (with a complete turn round each to avoid slipping) and so ensures all three wheels having the same angular motion which is also that of the arm LL: and the direction of a counting disc is accordingly $\theta+$ a constant, θ being the polar angular coordinate of the arm LL. The constant is easily adjusted to the zero for one disc and 90° for the other. The advantage of having the 3 wheels screw cut on their peripheries is that complete turns of the connecting wire may be applied without causing the turns of the wire to foul.

The counting discs are also pivoted on a horizontal axis so as to ride by their own weight only on the disc AA.

To enable the pointer of the portion MN to be caused to follow any given contour on a map without effort, a wheel S and shaft T are fitted. The shaft is screw cut and a wire extending the whole length of the arm LL (only a small portion of which is visible in the photo) is wrapped several times round the shaft. The turning of this wheel S traverses the part MN along the shaft LL. A counter weight to make movement in either direction approximately equally easy is attached by means of a wire passing round the wheels U V to the part M N. This weight is not visible in the photo: but the wire may be seen on the left. It is not taut as the weight was removed when the photo was taken to enable the whole instrument to be tilted over and so allow a better photograph to be taken.

When curvature of the earth is to be taken account of, this is done by so arranging that the wire dealing with the corresponding factor is pulled more or less up the vertical portion of M N by passing it round a pulley below and attaching its extremity to another pulley on a guide of suitable shape. This guide appropriately shaped for dealing with a map on the scale 32 miles = 1 inch is visible on the right of the photo.

The calibration of the integrator is easily performed by running the pointer round a contour of geometrical form, which enables the attractions to be calculated precisely.

The Seismograph.

The Omori Seismograph has been working throughout the year. The local earthquake of 29th August 1916 dislocated it, so that no proper record was obtained. The earthquakes recorded are tabulated below:—

Digitized by Google

List of earthquakes 1915-16.

Serial number.	Date.	Time of beginning (corrected).		Distance of Epicentre in miles.		Duration.	Intensity.	Remarks. Identification with any definitely ascertained earthquake.
		Dehra.	Simla*.	Dehra.	Simla*.			
1	4th Oct., 1915	12 52	12 42	9,800	9,000	1 25	Great.	
2	2nd Nov.	13 3½	13 4	3,570	5,000	2 15	Moderate.	
3	27th „	1 37	1 37	420	200	4	Slight.	
4	3rd Dec.	8 11	8 13	840	1,000	37	Great.	
5	18th „	12 38	12 38	840	1,000	28	Moderate.	
6	21st „	14 14	...	Local	...	...	Slight	
7	30th „	8 7½	8 7	700	600	7	Slight.	
8	2nd Jan., 1916	19 4	19 3	2,310	5,000	2 30	Great.	
9	14th „	12 ½	11 59	3,920	4,000	46	Do.	
10	14th „	14 2	14 1	3,850	4,000	1 32	Severe.	
11	25th „	12 33	12 32	2,240	2,500	1 14	Great.	
12	2nd Feb.	13 16	13 14	3,010	4,000	55	Do.	
13	7th „	3 33	3 31	5,040	6,000	1 15	Moderate.	
14	28th „	2 12½	2 12			2	Great.	
15	8th April	15 7	15 7	3,850	4,000	1 10	Moderate.	Japan.
16	16th „	18 9¾	18 10	2,800	3,500	44	Great.	
17	18th „	9 44	9 44	4,680	6,000	26	Moderate.	N.W. Pacific.
18	22nd „	17 9¾	17 11	6,500		54	Severe.	
19	22nd „	19 28	19 28	640		15	Slight.	
20	25th „	13 54½	13 54			1 52	Great.	
21	23rd June	1 27½		420		28	Slight.	
22	3rd Aug.	7 10¼	7 11	4,970	5,000	1 30	Moderate.	
23	29th „	12 10	12 10				Severe.	Instrument dislocated.
24	12th Sept.	12 10	12 10	3,570	3,000	30	Moderate.	

* The results of the Simla observations as published in the Daily Weather Report are also given for the sake of comparison. The Dehra estimates were made quite independently.

Solar Photography.

Negatives taken during 1915-16.

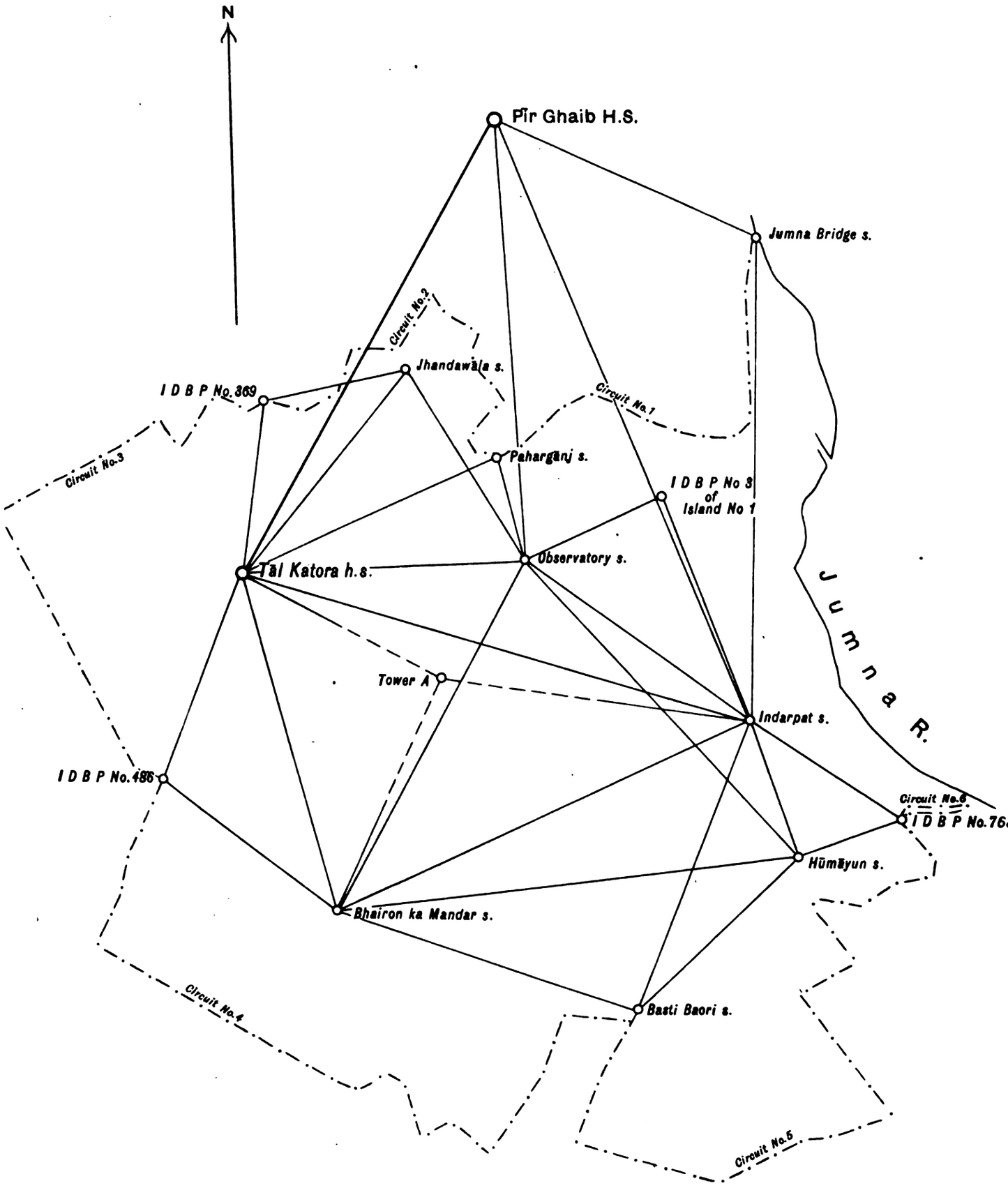
Month.	No. of days.	Sun invisible.	No. of 8″ Negatives.	No. of 12″ Negatives.	Month.	No. of days.	Sun invisible.	No. of 8″ Negatives.	No. of 12″ Negatives.
October ...	31	0	56	3	April ...	30	0	52	3
November ...	30	0	55	2	May ...	30	1	55	2
December ...	29	2	52	2	June ...	24	6	36	0
January ...	30	1	54	1	July ...	28	3	38	0
February ...	28	1	51	3	August ...	24	7	40	0
March ...	30	1	55	1	September ...	25	5	42	0
					Totals ...	339	27	586	17

Owing to cloudy state of weather no 12″ Negatives were taken from June to September 1916.

Digitized by Google

Digitized by Google

Diagram of the Triangulation and Traverse of the Imperial Delhi Area



Scale 1 1nch to 1 Mile

Digitized by Google

PART III.—SPECIAL REPORT.

TRAVERSE SURVEY OF THE BOUNDARY OF THE IMPERIAL DELHI AREA.

By E. C. J. Bond.

An accurate survey of the boundary of the Imperial Delhi Area, on the west side of the Jumna river, was asked for by the Chief Engineer, Public Works Department, Delhi, for preparing a skeleton plan to be filed with the Record of Rights. Mr. Bond, Officer in charge No. 18 Party, was placed in charge of the Base Line Party in addition to his other duties and directed to carry out the work. A detachment was formed, under Mr. O. N. Pushong, who was transferred to the party from No. 2 Drawing Office, to execute a traverse to determine accurately the bearings and distances between the 775 pillars of the boundary, which is about 30 miles in length, and also between the 200 pillars demarcating the boundaries of 13 small areas of unacquired land, within the Imperial Delhi Area, termed "Islands."

The necessary equipment was collected at the head quarters office at Dehra Dūn and the officer in charge proceeded to Delhi with the detachment on the 6th December 1915. On arrival at Delhi a reconnaissance was begun for a triangulation which was required to afford suitable points for the control of the traverse.

The reconnaissance was completed on the 15th December and a small experimental line of traverse was then run for a few days under the supervision of the officer in charge to train the detachment in the mode of procedure. During this test the Superintendent of the Trigonometrical Survey inspected the detachment.

After starting the triangulation the officer in charge returned to Dehra Dūn on the 20th December 1915.

He inspected the detachment again in the field on the 19th January and also a few days prior to the completion of the work on the 20th March when the detachment returned to Dehra Dūn.

The triangulation falls within the limits of the boundary and embraces an area of 22½ square miles. It is based on the side Pir Ghaib T. S.—Tāl Katora h. s. of the Great Arc Meridional Series.

The sides of the triangles are from 1 to 5 miles in length. 14 stations and 1 intersected point were fixed. Three of the stations are boundary pillars, *viz*:—Nos. 369, 486 and 768, and four others to which the boundary was connected are close to the boundary, *viz.*, Jumna Bridge s., Pahārganj s., Bhairon-ka-Mandar s. and Basti Baori s.

The rough sketch in this report illustrates the triangulation and the boundary.

The main triangle Pir Ghaib T. S.—Tāl Katora h.s.—Indarpat s. was observed on three zeros with a change of face on each zero and the remaining triangles on two zeros. A 6-inch transit theodolite by Troughton and Simms, reading to 10 seconds, was used.

Almost all the observations were taken to heliotropes and in only a few instances were opaque signals used, which were better for intersection at short distances than the dazzling flash of the helio.

A square tower on an eminence in the centre of the Imperial Delhi Area, named "Tower station A" by the Engineering Department, was well fixed by the triangulation. It is used by that department as the initial point from which all other points are laid out for the construction of the Government House buildings and for the alignment of roads to the north, south, east and west.

On the completion of the observations of the triangulation the traverse of the boundary was begun on the 23rd December. It was started from pillar No. 2 near the Jumna Bridge triangulation station, and carried along the boundary, counter-clockwise, up to pillar No. 776 near the right bank of the Jumna River opposite to Humāyūn's tomb. The last two pillars of the boundary, Nos. 777 and 778, were washed away by the erosion of the river bank.

The point of origin used for the traverse is Pir Ghaib T.S., of the Great Arc Meridional Series, situated on the "Ridge" at Delhi.

Digitized by Google

The traverse was divided into 5 circuits, each from 4 to 6 miles in length, and a small circuit about a mile long. Each circuit was connected at its initial and terminal points to a station of the triangulation: by this means the accumulation of error in the traverse is reduced and a satisfactory adjustment effected. The positions of the six circuits are shown in the rough diagram accompanying this report.

Circuit No. 1, which includes pillars 2 to 191, started from Jumna Bridge s. (No. 1 pillar was washed away by the river) and was run alongside the eastern and outer walls of the Delhi fort and round by the southern walls up to near the Ajmer Gate whence it branched off to the east of Pahārganj and skirting round the southern limits of this part of the town closed on Pahārganj s.

Circuit No. 2, which includes pillars 192 to 369, commenced from Pahārganj s., ran up in a northerly direction to the south-western limits of the Sadar Bazar quarter of the town and thence in a south-easterly direction and closed on pillar No. 369 of the boundary—one of the stations of the triangulation, situated a mile to the north of Tāl Katora h.s.

Circuit No. 3, which includes pillars 370 to 486, began from pillar No. 369 and proceeded for about 2 miles west by south, then turned southwards to a point a mile south of Todāpur village and branched off from there to pillar No. 486, which is common with the New Cantonment boundary pillar No. 43, where the circuit closed.

Circuit No. 4, which includes pillars 487 to 637, began from pillar No. 486 (one of the triangulation stations) and followed the rocky ridge on which it is situated in a southerly direction for a mile whence it left the ridge and ran for 3 miles south by east, then turned to the north-east for a mile and closed on Basti Baori s.

Circuit No. 5, which includes pillars 638 to 768, commenced from Basti Baori s. and proceeded three quarters of a mile south by west, then turned in an easterly direction to the G. I. P. Railway line and followed it for half a mile north-west of Kilōkri Railway Station; branching off from this point to the north-east for half a mile it again turned north-west to within half a mile of Humāyūn's tomb where it turned off to the north-east and closed on pillar No. 768 (a station of the triangulation) situated on the "Bēla" land east of Humāyūn's tomb.

Circuit No. 6, which includes pillars 769 to 776, began at pillar No. 768 and took a course due east to pillar No. 776 on the right bank of the Jumna river where the boundary ended; it then turned back and closed on the pillar from which it started.

Along circuit No. 1 it was not possible to observe at more than three out of the 168 pillars, as those along the east and south of the fort were close up to its walls and others round Pahārganj were also against walls of buildings and in the most filthy and inaccessible parts of the outskirts of this suburb. The traverse lines by the east walls of the fort had to be cleared through bulrushes which were most difficult to cut away and hampered the progress of the traverse to a considerable extent. The proximity of the boundary pillars to the walls of the fort and buildings necessitated many offsets and intersections being taken to them. For the first half of circuit No. 2 the pillars were mostly against buildings and for the remainder of the distance were over very rocky ground which made chaining difficult. In circuit No. 3 chaining was again difficult owing to rocks and boulders and the country being cut up with ravines. Measuring in circuit No. 4 was also laborious until the rocky ridges were passed and the traverse entered flat country, but here again other obstructions were met with in portions of ground covered with stunted shrubs of Indian crab-apple which had to be cut and cleared away for the chaining. In circuit No. 5, though the ground was very undulating, progress was easier, but again in circuit No. 6 slow headway was made owing to the thick growth of bulrushes which had to be cut away along the whole of this circuit.

Instruments used for the traverse and the methods employed.— A 6-inch transit theodolite by Troughton and Simms, reading to 10 seconds, was used. Particular care was taken to centre the theodolite accurately over each traverse station. Two measures of each angle were taken as in ordinary traversing. The boundary pillars were intersected by the theodolite in many instances where it was not possible or convenient to take offsets to them. Vertical angles were observed from one traverse station to another in order to reduce all measured distances to the horizontal; they were also taken for the same reason to boundary pillars, where found necessary.

The Abney level was used for any intermediate variations of slope.

Traverse signals.—The signals used consisted of a tripod and staff, illustrated and described in the Records, Volume IX. They were designed by Mr. J. de Graaff Hunter for

Digitized by Google

the traverse of the Bombay City Survey. The traverse staff can be easily and quickly adjusted and is of great advantage in correctly intersecting a point over which it is centred, when the point itself is not visible, as the staff is perfectly vertical when carefully adjusted. The good results obtained in the angular measurements are largely due to the employment of these staves which have proved so useful in this traverse survey.

100-foot steel tape.—This is a flat tape about 1/5 of an inch wide, graduated to feet along its whole length. It is wound on a small metal drum about 6 inches in diameter.

In measuring the distances between the traverse stations the tape was laid along the ground and carefully aligned. The near end of the tape is adjusted by bringing the zero exactly over the mark on the traverse station and is held down firmly. A spring balance is then attached to the forward end of the tape and a tension of 12 pounds applied and the complete tape length marked on a peg driven into the ground. The measurements were carried on in this manner from one peg to another until the tape approached the next traverse station where the measurement usually closed with a fractional part of the tape length which was read up to the last complete foot and any part in excess of the foot was measured by a metal scale and recorded to the 1/10 of an inch.

The tape was compared at intervals during the survey with the Invar standard tape and there was found to be a constant difference of 0·35 of an inch in excess of the standard.

Offsets were measured by an ordinary steel tape which agreed remarkably well with the standard.

Work during the recess.—The detachment was employed during the recess season on the computation of the triangulation and traverse of the Imperial Delhi Area boundary.

In the computation of the triangles which are based on the side Pir Ghaib T.S.—Tāl Katora h.s., 8 common sides were obtained and the average linear error from these is 0·1 foot per mile.

A great deal of work was involved in the computation of the direct distance and bearing from pillar to pillar owing to the many offsets and intersections taken to the boundary pillars.

The whole of the computations, including a list for publication, of the bearings and distances from pillar to pillar and the coordinates of each pillar, will be completed by the middle of December.

The average angular error of the traverse is 6 seconds and the linear error 1 in 9064.

TABLE II.—Details of Triangulation and Traversing by No. 19 Party at Delhi.

Triangulation.	Instrument used, Diameter in inches	6
	Area in square miles	22·5
	Square miles to each point fixed	1·5
	Square miles to each height	1·5
	Stations fixed	14
	Triangular error in seconds	11
	Linear error per mile in feet	0·1
	Intersected points: No. of points fixed	1
	Intersected points: Linear error per mile in feet ...	0·6
Traversing.	Linear miles chaining	29·8
	No. of stations at which theodolite was set up ...	457
	Angular error per station in seconds	6
	Linear error per 1,000	0·11

Digitized by Google

Digitized by Google

APPENDIX

List of Survey of India Publications

(Corrected up to 30th September 1916)

Digitized by Google

PUBLICATIONS

OF THE

SURVEY OF INDIA

SYNOPSIS

A—HISTORY AND GENERAL REPORTS.

		Page
MEMOIRS		99
ANNUAL REPORTS	General Reports	99
	Extracts from Narrative Reports	99
	Records of the Survey of India	100
SPECIAL REPORTS		100

B—GEODETIC WORKS OF REFERENCE.

EVEREST'S GREAT ARC BOOKS	100
G.T.S. VOLUMES	100
SYNOPTICAL VOLUMES	102
TRIANGULATION PAMPHLETS	103, 111
LEVELLING PAMPHLETS	103
TIDE TABLES	104

C—CATALOGUES AND INSTRUCTIONS.

DEPARTMENTAL ORDERS	104
CATALOGUES AND LISTS	105
TABLES AND STAR CHARTS	105
OLD MANUALS	105
SURVEY OF INDIA HAND-BOOKS	106
NOTES AND INSTRUCTIONS	106

D—MISCELLANEOUS PAPERS.

UNCLASSIFIED PAPERS	Geography, Special Reports	106, 107
	Geodesy, Projections, Mapping	107
PROFESSIONAL PAPERS		107
DEPARTMENTAL PAPERS		108
PROFESSIONAL FORMS		109
PUBLICATIONS OF THE ROYAL SOCIETY		109

AGENTS FOR THE SALE OF INDIAN OFFICIAL PUBLICATIONS ... 109

Digitized by Google

A—HISTORY AND GENERAL REPORTS.

(*Obtainable from the Superintendent Map Publication, 13, Wood Street, Calcutta*).

MEMOIRS.

1. A Memoir on the Indian Surveys. *By C. R. Markham* . India Office, London, 1871. *Price Rs. 5 or 6s/8d.*

2. Ditto (second edition). *By C. R. Markham, C.B., F.R.S.*, India Office, London, 1878. *Price Rs. 5-8 or 7s/4d.*

3. Abstract of the Reports of the Surveys and of other Geographical Operations in India, 1869-78. *By C. R. Markham and C. E. D. Black*, India Office, London. Published annually between 1871 and 1879. (Out of print).

4. A Memoir on the Indian Surveys, 1875—1890. *By C.E.D. Black*, India Office, London 1891. *Price Rs. 5-8 or 7s/4d.*

ANNUAL REPORTS.

Reports of the **Revenue Branch** . 1851 to 1877.—(1851-67 and 1869-70, out of print). *Price Rs. 3 or 4s.*

Ditto **Topographical Branch** . 1860 to 1877.—(Out of print).

Ditto **Trigonometrical Branch** . 1861 to 1878.—(1861-71, out of print). *Price Rs. 2 or 2s/8d.*

In 1878 the three branches were amalgamated, and from that date onwards annual reports in single volumes for the whole department, are available as follows:—

General Reports { from 1877—1900 (1877-79, 1887-88, 1895-96 and 1897-98, out of print). *at Rs. 3 or 4s per volume.*
from 1900—1916 (1902-04 and 1906-08, out of print) *at Rs. 2 or 2s/8d per volume.*

From 1900 onwards the Report has been issued annually in the form of a condensed statement known as the **"General Report"** supplemented by fuller reports, which were called **"Extracts from Narrative Reports"** up to 1909, and since then have been styled **"Records of the Survey of India."** These fuller reports are available as follows:—

(*a*) **"Extracts" Volumes** *at Rs. 1-8 or 2s per volume.*

1900-01—Recent Improvements in Photo-Zincography. G. T. Triangulation in Upper Burma. Latitude Operations. Experimental Base Measurement with Jäderin Apparatus. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Calcutta, 1903. (Out of print).

1901-02—G. T. Triangulation in Upper Burma. Latitude Operations. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Topography in Sind. Topography in the Punjab. Calcutta, 1904. (Out of print.)

1902-03—Principal Triangulation in Upper Burma. Topography in Upper Burma. Topography in Shan States. Survey of Sāmbhar Lake. Latitude Operations. Tidal and Levelling. Magnetic Survey. Introduction of the Contract System of Payment in Traverse Surveys. Traversing with the Subtense Bar. Compilation and Reproduction of Thāna Maps. Calcutta, 1905.

1903-04—Magnetic Survey. Pendulum. Tidal and Levelling. Astronomical Azimuths. Utilization of old Traverse Data for Modern Surveys in the United Provinces. Identification of Snow Peaks in Nepāl. Topographical Surveys in Sind. Notes on town and Municipal Surveys. Notes on Riverain Surveys in the Punjab. Calcutta, 1906.

1904-05—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Survey Operations with the Somaliland Field Force. Calcutta, 1907.

1905-06—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Topography in Shan States. Calcutta, 1908.

1906-07—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Astronomical Latitudes. Topography in Shan States. Calcutta, 1909.

1907-08—Magnetic Survey. Tidal and Levelling. Astronomical Latitudes. Pendulum Operations. Topography in Shan States. Calcutta, 1910.

1908-09—Magnetic Survey. Tidal and Levelling. Pendulum Operations. Triangulation. Calcutta, 1911.

Digitized by Google

ANNUAL REPORTS—(*Continued*).

(*b*) **"Records of the Survey of India"** *at Rs. 4 or 5s/4d per volume, except where otherwise stated.*

Vol. I—**1909-10**—Annual reports of parties and offices ... ... Calcutta, 1912.
II—**1910-11**—Annual reports of parties and offices ... ... Calcutta, 1912.
III—**1911-12**—Annual reports of parties and offices ... ... Calcutta, 1913.
IV—**1911-13**—*Explorations on the North-East Frontier* ... ... Calcutta, 1914.
V—**1912-13**—Annual reports of parties and offices ... ... Calcutta, 1914.
VI—**1912-13**—*Link connecting the Triangulations of India and Russia* . Dehra Dūn, 1914.
VII—**1913-14**—Annual reports of parties and offices ... ... Calcutta, 1915.
VIII—{ **1865-79—Part I** / **1879-92—Part II** } *Explorations in Tibet and neighbouring regions* { Dehra Dūn, 1915. *Price of each Part Rs. 4 or 5s/4d.*
IX—**1914-15**—Annual reports of parties and offices ... ... Calcutta, 1916.
X—**1915-16**—Annual reports of parties and offices ... Dehra Dūn, 1917.

SPECIAL REPORTS.

1. *Report on the Mussoorie and Landour, Kumaun and Garhwāl, Ranikhet and Kosi Valley Surveys extended to Peshāwar and Khāgān Triangulation during 1869-70 *By Major T. G. Montgomerie, R.E.* (Out of print).

2. *Account of the Survey Operations in connection with the Mission to Yārkand and Kashghar in 1873-74. *By Captain Henry Trotter, R.E.* Calcutta, 1875.

3. Report on the Trans-Himālayan Explorations during 1869. (Out of print).

4. Report on the Trans-Himālayan Explorations during 1870. Dehra Dūn, 1871. (Out of print).

5. Report on the Trans-Himālayan Explorations during 1878. Calcutta, 1880. (Out of print).

"Notes of the Survey of India" are issued monthly. (Stocked in the Surveyor General's Office, Calcutta). *Price as. 2 or 2d.*

B—GEODETIC WORKS OF REFERENCE.

(Obtainable from the Superintendent of the Trigonometrical Survey, Dehra Dūn, U.P.)

EVEREST'S GREAT ARC BOOK.

1. An account of the Measurement of an Arc of the Meridian between the parallels of 18° 3′ and 24° 7′ ... ... East India Company, London, 1830. (Out of print.)

2. An account of the Measurement of two Sections of the Meridional Arc of India, bounded by the parallels of 18° 3′ 15″, 24° 7′ 11″, and 29° 30′ 48″. East India Company, London, 1847. (Out of print.)

3. Engravings to illustrate the above. London, 1847, (Out of print.)

G.T.S. VOLUMES—describing the Operations of the Great Trigonometrical Survey.

Price Rs. 10-8 or 14s per volume, except where otherwise stated.

Vol. I—**Standards of Measure and Base-Lines,** also an Introductory Account of the early Operations of the Survey, during the period of 1800-1830. Dehra Dūn, 1870. (Out of print.)

Appendix No. 1. Description of the method of comparing, and the apparatus employed.
Appendix No. 2. Comparisons of the Lengths of 10-feet Standards **A** and **B**, and determinations of the Difference of their Expansions.
Appendix No. 3. Comparisons between the 10-feet Standards I_B I_S and **A**.
Appendix No. 4. Comparisons of the 6-inch Brass Scales of the Compensated Microscopes.
Appendix No. 5. Determination of the Length of the Inch [7.8] on Cary's 3-foot Brass Scale.
Appendix No. 6. Comparisons between the 10-feet Standard Bars I_S and **A** for determining the Expansion of bar **A**.
Appendix No. 7. Final determination of the Differences in Length between the 10-feet Standards I_B I_S and **A**.
Appendix No. 8. On the Thermometers employed with the Standards of Length.
Appendix No. 9. Determination of the Lengths of the Sub-divisions of the Inch [*a.b*].
Appendix No. 10. Report on the Practical Errors of the Measurement of the Cape Comorin Base.

II—**A History and General Description of the Reduction** of the Principal Triangulation. ... Dehra Dūn, 1879. (Out of print.)

Appendix No. 1. Investigations applying to the Indian Geodesy.
Appendix No. 2. The Micrometer Microscope Theodolites.
Appendix No. 3. On Observations of Terrestrial Refraction at certain stations situated on the plains of the Punjab.
Appendix No. 4. On the Periodic Errors of Graduated Circles, &c.
Appendix No. 5. On certain Modifications of Colonel Everest's System of Observing introduced to meet the specialities of particular instruments.
Appendix No. 6. On Tidal Observations at Kurrachee in 1855.
Appendix No. 7. An alternative Method of obtaining the Formulæ in Chapters VIII and XV employed in the Reduction of Triangulation.—Additional Formulæ and Demonstrations.

---

* For Departmental use only.

Digitized by Google

G.T.S. VOLUMES—(*Continued*).

Appendix No. 8. On the Dispersion of Circuit Errors of Triangulation after the Angles have been corrected for Figural conditions.

Appendix No. 9. Corrections to azimuthal Observations for imperfect Instrumental Adjustments.

Appendix No. 10. Reduction of the N.W. Quadrilateral—the Non-Circuit Triangles and their Final Figural Adjustments.

Appendix No. 11. The Theoretical Errors of the Triangulation of the North-West Quadrilateral.

Appendix No. 12. Simultaneous Reduction of the N.W. Quadrilateral—the Computations.

III—**North-West Quadrilateral.**—The Principal Triangulation, the Base-Line Figures, the Karāchi Longitudinal, N. W. Himālaya, and the Great Indus Series. ... ... Dehra Dūn, 1873. (Out of print.)

IV—**North-West Quadrilateral**—The Principal Triangulation, the Great Arc—Section 24°—30°, Rahūn, Gurhāgarh and Jogi-Tīla Meridional Series and the Sutlej Series. ... ... Dehra Dūn, 1876.

IVA—**North-West Quadrilateral**—The Principal Triangulation, the Jodhpore and the Eastern Sind Meridional Series with the details of their Reduction and the Final Results. ... ... Dehra Dūn, 1886.

V—**Pendulum Operations** of Captains J. P. Basevi and W. J. Heaviside, and their Reduction. Dehra Dūn and Calcutta, 1879.

Appendix No. 1. Account of the Remeasurement of the Length of Kater's Pendulum at the Ordnance Survey Office, Southampton.

Appendix No. 2. On the Relation between the Indian Pendulum Operations, and those which have been conducted elsewhere.

Appendix No. 3. On the Theory, Use and History of the Convertible Pendulum.

Appendix No. 4. On the Length of the Seconds Pendulum determinable from Materials now existing.

Appendix No. 5. A Bibliographical List of Works relating to Pendulum Operations in connection with the Problem of the Figure of the Earth.

VI—**South-East Quadrilateral**—The Principal Triangulation and Simultaneous Reduction of the following Series:—Great Arc—Section 18° to 24°, the East Coast, the Calcutta and the Bider Longitudinal, the Jabalpur and the Bilāspur Meridionals. ... ... Dehra Dūn, 1880. (Out of print.)

VII—**North-East Quadrilateral**—General Description and Simultaneous Reduction. Also details of the following five series:—North-East Longitudinal, the Budhon Meridional, the Rangir Meridional, the Amua Meridional, and the Karāra Meridional. ... ... Dehra Dūn, 1882.

Appendix No. 1. The Details of the Separate Reduction of the Budhon Meridional Series or Series J of the North-East Quadrilateral.

Appendix No. 2. Reduction of the North-East Quadrilateral. The Non-circuit Triangles and their Final Figural Adjustments.

Appendix No. 3. On the Theoretical Errors Generated Respectively in Side, Azimuth, Latitude and Longitude in a Chain of Triangles.

Appendix No. 4. On the Dispersion of the Residual Errors of a Simultaneous Reduction of Several Chains of Triangles.

Vol. VIII—**North-East Quadrilateral**—Details of the following eleven series:—Gurwāni Meridional, Gora Meridional, Hurīlāong Meridional, Chendwār Meridional, North Pārasnāth Meridional, North Malūncha Meridional, Calcutta Meridional, East Calcutta Longitudinal, Brahmaputra Meridional, Eastern Frontier—Section 23° to 26°, and Assam Longitudinal. ... Dehra Dūn, 1882.

IX—**Telegraphic Longitudes**—during the years 1875-77 and 1880-81. Dehra Dūn, 1883.

Appendix to Part I. 1. Determination of the Geodetic Elements of Longitude Stations.
2. Descriptions of Points used for Longitude Stations.
3. Comparison of Geodetic with Electro-Telegraphic Arcs of Longitude.
4. Circuit Errors of Observed Arcs of Longitude.
5. Results of Idiometer Observations made during Season 1880-81.

Appendix to Part II. 1. Situations of the Longitude Stations at Bombay, Aden and Suez.
2. Survey Operations at Aden.
3. Results of the Triangulation.
4. Right Ascensions of Clock Stars.

X—**Telegraphic Longitudes**—during the years 1881-82, 1882-83, and 1883-84. Dehra Dūn, 1887.

Appendix to Part I. 1. Determination of the Geodetic Elements of the Longitude Stations.
2. Descriptions of Stations of the Connecting Triangulation and of those at which the Longitude Observations were taken.
3. On the Errors in ΔL caused by Armature-time and the Retardation of the Electric Current.
4. On the Rejection of some doubtful Arcs of Season 1881-82.
5. On the probable Causes of the Errors of Arc-measurements, and on the Nature of the Defects in the Transit Instruments which might produce them.

Digitized by Google

G.T.S. VOLUMES—(*Continued*).

XI—**Astronomical Latitudes**—during the period 1805-1885 Dehra Dūn, 1890.

XII—**Southern Trigon**—General Description and Simultaneous Reduction. Also details of the following two series:—Great Arc—Section 8° to 18°, and Bombay Longitudinal. ... ... Dehra Dūn, 1890.

XIII—**Southern Trigon**—Details of the following five series:—South Konkan Coast, Mangalore Meridional, Madras Meridional and Coast, South-East Cost, and Madras Longitudinal. ... ... Dehra Dūn, 1890.

XIV—**South-West Quadrilateral**—Details of Principal Tringulation and Simultaneous Reduction of its component series. ... Dehra Dūn, 1890.

XV—**Telegraphic Longitudes**—from 1885 to 1892 and the Revised Results of Volumes IX and X: also the Simultaneous Reduction and Final Results of the whole Operations. ... ... Dehra Dūn, 1893.

Appendix No 1. Determination of the Geodetic Elements of the Longitude Stations.

Appendix N . 2. On Retardation (a numerical mistake was made in this appendix in the conversion of a formula from kilometres to miles: the conclusions drawn cannot therefore be upheld).

XVI—**Tidal observations**—from 1873 to 1892, and the Methods of Reduction. Dehra Dūn, 1901.

XVII—**Telegraphic Longitudes**—during the years 1894-95-96. The Indo-European Arcs from Karāchi to Greenwich. .. ... Dehra Dūn, 1901.

Appendix No. 1. Descriptions of Points used for Longitude Stations.

Appendix No. 2. The Longitude of Madras.

XVIII—**Astronomical Latitudes** from 1885 to 1905 and the Deduced Values of Plumb-line Deflections. ... ... Dehra Dūn, 1906.

Appendix No. 1. On Deflections of the Plumb-line in India

Appendix No. 2. Determination of the Geodetic Elements of the Latitude Stations of Bajamara, Bahak, Lambatach and Kidarkanta.

Appendix No. 3. On the (N—S) Difference exhibited by Zenith Sector No. 1.

Appendix No. 4. On the Value of the Micrometer of the Zenith Telescope.

Appendix No. 5. On the Azimuth Observations of the Great Trigonometrical Survey of India.

Appendix No. 6. A Catalogue of the Publications of the Great Trigonometrical Survey of India.

Appendix No. 7. On the combination weights employed.

XIX—**Levelling of Precision in India** from 1858 to 1909. Dehra Dūn, 1910.

Appendix No. 1. Experiment to test the changes, due to Moisture and Temperature, in the Length of a Levelling Staff.

Appendix No. 2. On the erection of Standard Bench-Marks in India during the years 1904-1910.

Appendix No. 3. Memorandum on the steps taken in 1905-1910 to enable movements of the Earth's crust to be detected.

Appendix No. 4. Dynamic and Orthometric corrections to the Himalayan levelling lines and circuit; and a consideration of the order of magnitude of possible refraction errors.

Appendix No. 5. The passage of rivers by the Levelling Operations.

Appendix No. 6. The Errors of the Trigonometrical values of Heights of stations of the principal triangulation.

Appendix No. 7. The effect on the spheroidal correction of employing Theoretical instead of Observed values of Gravity and a discussion of different formulæ giving variation of Gravity with Latitude and Height.

Appendix No. 8. On the discrepancy between the Trigonometrical and spirit-level values of the difference of height between Dehra Dūn and Mussooree.

XIXA—**Bench-Marks** on the **Southern** Lines of Levelling. Dehra Dūn, 1910.
Price Rs. 5 or 6s/8d.

XIXB—**Bench-Marks** on the **Northern** Lines of Levelling. Dehra Dūn, 1910.
Price Rs. 5 or 6s/8d.

SYNOPTICAL VOLUMES—giving charts, descriptions of stations, and full synopses of coordinates and heights of all stations and points fixed by Principal and Secondary **Triangulation**.*

Price Rs. 2 or 2s/8d per volume unless otherwise stated.

Italic figures are in chronological order and refer to the Index Chart of the G. T. Survey.

North-West Quadrilateral

Vol. I—The Great Indus Series (*32*). Dehra Dūn, 1874.

II—The Great Arc—Section 24° to 30° (*6*). Dehra Dūn, 1874.

III—The Karachi Longitudinal Series (*25*). Dehra Dūn, 1874.

IV—The Gurhāgarh Meridional Series (*23*). Dehra Dūn, 1875.

V—The Rahūn Meridional Series (*33*). Dehra Dūn, 1875.

VI—The Jogi-Tila Meridional Series (*37*). and the Sutlej Meridional Series (*45*). Dehra Dūn, 1875.

VII—The N. W. Himālaya Series (*22*) and the Triangulation of Kashmīr (*36*). Dehra Dūn, 1879.

VIIA—The Jodhpore Meridional Series (*62*) and the Eastern Sind Meridional Series (*64*). Dehra Dūn, 1887.

* Special charts can be supplied of those series for which no Synoptical Volumes are available, *viz.*:—all Burma, Chittagong and Baluchistān triangulation, the Assam Longitudinal, the Sambalpur Meridional, and the Gilgit Series, with a few recent secondary series in India.

Digitized by Google

SYNOPTICAL VOLUMES—(*Continued*)

South-East Quadrilateral

Vol. VIII—The Great Arc—Section 18° to 24° (*8*). Dehra Dūn, 1878.
IX—The Jabalpur Meridional Series (*53*). Dehra Dūn, 1878.
X—The Bider Longitudinal Series (*43*). Dehra Dūn, 1880.
XI—The Bilāspur Meridional Series (*58*). Dehra Dūn, 1880.
XII—The Calcutta Longitudinal Series (*5*). Dehra Dūn, 1880
XIII—The East Coast Series (*24*). Dehra Dūn, 1880.
XIIIA—The South Pārasnāth (*1*) and the South Malūncha Meridional Series (*17*). Dehra Dūn, 1885.

North-East Quadrilateral

Vol. XIV—The Budhon Meridional Series (*2*). Dehra Dūn, 1883.
XV—The Rangīr Meridional Series (*4*). Dehra Dūn, 1883.
XVI—The Amua Meridional Series (*3*) and the Karāra Meridional Series (*12*). Dehra Dūn, 1883.
Vol. XVII—The Gurwāni Meridional Series (*19*) and the Gora Meridional Series (*15*). Dehra Dūn, 1883.
XVIII—The Hurīlāong Meridional Series (*21*) and the Chendwār Meridional Series (*14*). Dehra Dūn, 1883.
XIX—The North Pārasnāth (*27*) and the North Malūncha Meridional Series (*13*). Dehra Dūn, 1883.
XX—The Calcutta Meridional (*16*) and the Brahmapūtra Meridional Series (*56*). Dehra Dūn, 1883.
XXI—The East Calcutta Longitudinal (*48*) and the Eastern Frontier Series—23° to 26° (*44*). Dehra Dūn, 1883.
XXII—The Assam Valley Triangulation, E. of Meridian 92° (*55*). Dehra Dūn, 1891. (Out of print.)
XXXV—The North-East Longitudinal Series (*20*) with the volume of charts. Dehra Dūn, 1909. *Price Rs. 5 or 6s/8d.*

Southern Trigon

Vol. XXIII—The South Konkan Coast Series (*11*). Dehra Dūn, 1891.
XXIV—The Mangalore Meridional Series (*49*). Dehra Dūn, 1891.
XXV—The South-East Coast Series (*63*). Dehra Dūn, 1891.
XXVI—The Bombay Longitudinal Series (*7*). Dehra Dūn, 1892.
XXVII—The Madras Longitudinal Series (*54*). Dehra Dūn, 1892.
XXVIII—The Madras Meridional and Coast Series (*46*). Dehra Dūn, 1892.
XXIX—The Great Arc Meridional Series—Section 8° to 18° (*9*). Dehra Dūn, 1899.

South-West Quadrilateral

Vol. XXX.—The Abu Meridional Series (*26*) and the Gujarāt Longitudinal Series (*29*). Dehra Dūn, 1892.
XXXI—The Khānpisura Meridional Series (*18*). Dehra Dūn, 1893.
XXXII—The Singi Meridional Series (*10*). Dehra Dūn, 1893.
XXXIII—The Cutch Coast Series (*35*). Dehra Dūn, 1893.
Addendum to the Cutch Coast Series, (*Indus delta*) (separate pamphlet). Dehra Dūn, 1902.
XXXIV—The Kāthiāwār Meridional Series (*28*). Dehra Dūn, 1894.

TRIANGULATION PAMPHLETS with charts, are now being issued for every square degree, giving the results of all minor triangulation, as well as that shown in Synoptical Volumes *Price Re. 1 or 1s/4d per pamphlet.* *Vide* page 111.

LEVELLING PAMPHLETS—giving heights and descriptions of all **Bench-marks**, fixed by levelling of Precision in India and Burma. Each pamphlet embraces an area of 4° × 4° and the numbering is the same as that of the corresponding sheets of the 1/M map of India. Each is illustrated by a map of the area. *Price Rs. 2 or 2s/8d per pamphlet except where otherwise stated.*

Pamphlet	Nos.	Latitude.	Longitude.	Published		Pamphlet	Nos.	Latitude.	Longitude	Published.	
India	**84**	28°–32°	64°–68°	Dehra Dūn,	1916.	India	**57**	12°–16°	76°–80°	Dehra Dūn,	1912.
„	**85**	24°–28°	64°–68°	„	1911.	„	**58**	8°–12°	76°–80°	„	1914.
„	**88**	32°–36°	68°–72°	„	1912.	„	**63**	24°–28°	80°–84°	„	1911.
„	**89**	28°–32°	68°–72°	„	1913.						
„	„	Addendum			(*at press*)	„	**64**	20°–24°	80°–84°	„	1912.
„	**40**	24°–28°	68°–72°	„	1911	„	**65**	16°–20°	80°–84°	„	1913.
„	**41**	20°–24°	68°–72°	„	1913	„	**66**	12°–16°	80°–84°	„	1912.
„	**43**	32°–36°	72°–76°	„	1913	„	**72**	24°–28°	84°–88°	„	1912.
„	„	Addendum		„	1915	„	**73**	20°–24°	84°–88°	„	1913.

Digitized by Google

LEVELLING PAMPHLETS—(*Continued*)

Pamphlet	Nos.	Latitude.	Longitude.	Published.		Pamphlet	Nos.	Latitude.	Longitude.	Published.	
India	**44**	28°–32°	72°–76°	Dehra Dūn,	1912	India	**74**	16°–20°	84°–88°	Dehra Dūn,	1913.
„	**45**	24°–28°	72°–76°	„	1911	„	**78**	24°–28°	88°–92°	„	1912.
„	**46**	20°–24°	72°–76°	„	1912	„	„*	Addendum		„	1916.
„	**47**	16°–20°	72°–76°	„	1912	„	**79**	20°–24°	88°–92°	„	1912.
„	„*	Addendum		„	1915	„	„	Addendum		„	1916.
„	**48**	12°–16°	72°–76°	„	1912	„	**83**	24°–28°	92°–96°	„	1912.
„	**49***	8°–12°	72°–76°	„	1911	Burma	**84**	20°–24°	92°–96°	„	1911.
„	**52**	32°–36°	76°–80°	„	1912	„	„	Addendum		„	1914.
„	**53**	28°–32°	76°–80°	„	1912	„	**85**	16°–20°	92°–96°	„	1913.
„	**54**	24°–28°	76°–80°	„	1914†	„	**92**	24°–28°	96°–100°	„	1911.
„	**55**	20°–24°	76°–80°	„	1912	„	**93**	20°–24°	96°–100°	„	1911.
„	**56**	16°–20°	76°–80°	„	1912	„	**94**	16°–20°	96°–100°	„	1911.

* Price Re. 1 or *1s/4d*.

† 2nd Edition (enlarged).

TIDE TABLES—

Since 1881 Tidal predictions based on the observations of the Survey of India have been published annually by the India Office, London. The tables give the time and height of high and low water for every day in the year at each port, and are published early in the previous year. Current tables are available for the following 40 ports :—

Western Ports—

Suez (Egypt)—Perim—Aden—Maskat—Būshire—Karachi—Okha Point and Bet Harbour (Gulf of Cutch)—Porbandar—Port Albert Victor (Kāthiāwār)—Bhaunagar—Bombay (Apollo Bandar)—Bombay (Prince's Dock)—Mormugao (Goa)—Kārwār—Beypore (near Calicut)—Cochin—Minicoy (Indian Ocean)—Tuticorin—Pāmban Pass (Island of Rāmeswaram).

Eastern Ports—

Galle (Ceylon)—Trincomalee (Ceylon)—Colombo (Ceylon)—Negapatam—Madras—Cocanāda—Vizagapatam—False-Point—Dublat (Saugor Island)—Diamond Harbour—Kidderpore (Calcutta)—Chittagong—Akyab—Diamond Island (Burma)—Bassein—Elephant Point (Burma)—Rangoon—Amherst—Moulmein—Mergui—Port Blair

The Tide Tables are issued in the following forms :—

(i) **Combined Volume**—including all the above ports—*Price Rs. 4 or 5s/4d*.

(ii) **Part I and Part II**—including Western and Eastern ports respectively—*Each part Rs. 2 or 2s/8d*.

(iii) **Pamphlets**—giving separately the tables for individual ports or for small local groups of ports—*Price varying from As. 8 or 8d to Rs. 1-8 or 2s per pamphlet.*

C—CATALOGUES AND INSTRUCTIONS.

(*Obtainable from the Superintendent, Map Publication, 13, Wood Street, Calcutta*).

DEPARTMENTAL ORDERS.

From 1878 to 1885 the Surveyor General's orders were all issued as "*Circular Orders.*" Since then they have been classified as follows :—

From 1885 to 1904 as
- **1—Goverment of India Orders** (called "*Circular Orders*" up to 1898.)
- **2—Departmental Orders (Administrative).**
- **3—Departmental Orders (Professional).**

In 1904 the various orders issued since 1878 were reclassified as follows :—

	Number to date.
1.—Government of India Orders.—	677
2.—Circular Orders (Administrative).—	350
3.—Circular Orders (Professional).—	190
4.—Departmental Orders. (appointments, promotions, transfers, etc.)	

These are numbered serially and had reached the above numbers by September 1916. *Government of India Orders and Circular Orders* (*Administrative*) are bound up in volumes from time to time, as shown below, while *Circular Orders* (*Professional*) are gradually incorporated in the Survey Hand-books. Besides the above, temporary orders have been issued since 1910 in the form of "**Circular Memos.**" These either lapse or become incorporated in some more permanent form, and are therefore only numbered serially for each year. Bound volumes of orders are available as follows:—

1. *Government of India Orders (Departmental) 1878-1903.—Calcutta, 1904.
   Ditto ditto 1904-1908.—Calcutta, 1909. (Out of print).
   Ditto ditto 1909-1913.—Calcutta, 1915.
2. *Circular Orders (Administrative) 1878-1903.—Calcutta, 1904. *Price Rs. 1-4 or 1s/8d*.
   Ditto ditto 1904-1908.—Calcutta, 1909. „ *As. 6 or 6d*.
   Ditto ditto 1909-1913.—Calcutta, 1915. „ *As. 8 or 8d*.

* For Deparmental use only.

Digitized by Google

DEPARTMENTAL ORDERS—(*Continued*)

3. * Regulations on the subject of Language Examinations for Officers of the Survey of India. Calcutta, 1914.

4. * Map Publication Orders 1908-1914 (*Superintendent, Map Publication's Orders.*)—Calcutta, 1914.

5. Specimens of papers set at Examinations for the Provincial Service.—Dehra Dūn, 1903.—(Out of print).

CATALOGUES AND LISTS.

1. **Catalogue of Maps** published by the Survey of India. Second edition. Calcutta 1915. *Price Re. 1 or 1s/4d.*

NOTE.—Lists are issued quarterly of new maps published during each quarter, and similar lists for each month appear in the monthly NOTES OF THE SURVEY OF INDIA.

2. **Catalogue of Maps** of the Bombay Presidency, Calcutta, 1913. *Price As. 4 or 4d.*

3 **List of Survey of India publications** (published annually)—*Gratis.*

4. **Price List of Mathematical Instrument Office.** Calcutta, 1913. *Gratis.*

5. Catalogue of Books in the Head-Quarters Library, Calcutta, 1901. (Out of print).

6. Catalogue of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1 or 1s/4d.*

7. Catalogue of Books in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1911. (Out of print.)

8. **Green Lists**—PART I—List of officers in the Survey (*half yearly to dates 1st January and 1st July*)—Calcutta. *Price As. 6 or 6d.*

PART II—History of Services of Officers of the Survey of India (*annually to date 1st July*)—Calcutta. *Price As. 8 or 8d.*

9. **Blue Lists**—Ministerial and Subordinate Establishments of the Survey of India.

PART I—Head quarters and Dehra Dūn offices (published annually to date 1st April)—Calcutta. *Price Re. 1 or 1s/4d.*

PART II—Circles and parties (published annually to date 1st January).—Calcutta. *Price Rs. 1-8 or 2s.*

(Nos. 8 and 9 are stocked in the Surveyor General's Office, Calcutta).

TABLES AND STAR CHARTS.

1. **Auxiliary Tables**—to facilitate the calculations of the Survey of India. Fourth Edition, revised. Dehra Dūn, 1906. *Price Rs. 4 or 5s/4d in cloth and calf, or Rs. 2 or 2s/8d in paper and boards.*

2. **Auxiliary Tables**—to facilitate the calculations of the Survey of India. Fifth Edition, revised and extended. PART I—Graticules of Maps. Dehra Dūn, 1916. *Price Re. 1 or 1s/4d.*

3. Tables for Graticules of Maps. Extracts for the use of **Explorers.** Dehra Dūn, 1910. *Price As. 4 or 4d.*

4. * Metric Weights and measures and other Tables. Photo-Litho Office. Calcutta, 1889. (Out of print.)

5. Logarithmic Sines and Cosines to 5 places of decimals. Dehra Dūn, 1886. *Price As. 4 or 4d.*

6. Logarithmic Sines, Cosines, Tangents and Cotangents to 5 places of decimals. Dehra Dūn, 1915. *Price Re. 1 or 1s/4d.*

7. Common Logarithms to 5 places of decimals. *Price As. 4 or 4d.*

8. Table for determining Heights in Traversing. Dehra Dūn, 1898. *Price As. 8 or 8d.*

9. Tables of distances in Chains and Links corresponding to a subtense of 20 feet. Dehra Dūn, 1889. *Price As. 4 or 4d.*

10. *	Ditto	ditto	10 feet.	Calcutta, 1915.
11. *	Ditto	ditto	8 feet.	Ditto.

12. Star Charts for latitude 20° N. *By Colonel J. R. Hobday, I.S.C.* Calcutta, 1900. (Out of print).

13. Star Charts for latitude 30° N. *By Lt.-Col. Burrard, R.E., F.R.S.* Dehra Dūn, 1906. *Price Rs. 1-8 or 2s.*

14. * Catalogue of 249 Stars for epoch Jan. 1, 1892, from observations by the Survey. Dehra Dūn, 1893. (Out of print.)

15 * Rainfall from 1868 to 1903, measured at the G. T. Survey Office. Dehra Dūn. (Out of print.)

OLD MANUALS.

1. A Manual of Surveying for India, detailing the mode of operations on the Revenue Surveys in Bengal and the North-Western Provinces. Compiled *by Captains R. Smyth and H. L. Thuillier.* Calcutta 1851. (Out of print.)

2. Ditto ditto ditto. Second Edition. London, 1855. *Price Rs. 4 or 5s/4d.*

3. A Manual of Surveying for India, detailing the mode of operations on the Trigonometrical, Topographical and Revenue Surveys of India. Compiled *by Colonel H. L. Thuillier, C.S.I., F.R.S., and Lieutenant-Colonel R. Smyth.* Third Edition, revised and enlarged. Calcutta, 1875. (Out of print.)

4. **Hand-book, Revenue Branch.** Calcutta, 1893. *Price Rs. 2-8 or 3s/4d.*

* For Departmental use only.

Digitized by Google

SURVEY OF INDIA HAND-BOOKS.

1. **Hand-book of General Instructions,** Fourth Edition. Calcutta, 1914. *Price Rs. 3 or 4s.*

2. **Hand-book, Trigonometrical Branch,** Second Edition. Calcutta. (Out of print.)

3. **Hand-book, Topographical Branch,** Third Edition. Calcutta, 1905. (Out of print.)

*The following chapters of a revised edition of **the Topo. Hand-book** are available for issue in pamphlet forms:— *Price As. 8 or 8d per copy or Rs. 3 or 4s per set.*

Chapter I—Introductory.
" II—Constitution and Organization of a Survey Party.
" III—Triangulation and its Computation.
" IV—Traversing and its Computation.
" V—Plane-tabling.
" VI—Fair Mapping.
" VII—Trans-frontier Reconnaissance.
" IX—Forest Surveys and Maps.
" X—Reproduction of the Sheets of the one-inch Map.

4. ***Photo-Litho Office,** Notes on Organization, Methods and Processes. Calcutta, 1914.

5. **The Reproduction (for the guidance of other Departments),** of Maps, Plans, Photographs, Diagrams, and Line Illustrations. Calcutta, 1914. *Price Rs. 3 or 4s.*

NOTES AND INSTRUCTIONS.

Drawing and Paper.

1. *Notes on the Drawing of New Standard Maps. *By Major W. M. Coldstream, R.E.* Calcutta, 1908.

2. *Notes on Printing Papers suitable for Maps, and on Whatman Drawing Paper. *By Major W. M. Coldstream, R. E.* Calcutta, 1911.

Printing and Field Litho processes.

3. *Report on Rubber Offset Printing for Maps. *By Major W. M. Coldstream, R. E.* Calcutta, 1911.

4. *Notes on the "Vandyke" or Direct Zinc Printing Process, with details of Apparatus and Chemicals required for a small section. Compiled in the Photo and Litho Office, Survey of India. Calcutta, 1913. *Price Re. 1 or 1s/4d.*

5. *Report on the Working of the Light Field Litho Press (experimental) in November and December 1910 with Appendices. *By Lieutenant A. A. Chase, R. E.,* Calcutta, 1911.

(1) Notes on some of the Methods of Reproduction suitable for the Field.

(2) Suggested Equipment Tables for the Light Field Litho Press (experimental).

6. *Report on a trial of the equipment of the 1st (Prince of Wales' Own) Sappers and Miners for reproducing maps in the field. *By Lieutenant A. A. Chase, R. E.* Calcutta, 1912.

Base Lines and Magnetic.

7. *Notes on use of the Jäderin Base-line Apparatus. Dehra Dun. 1904.

8. *Miscellaneous Papers relating to the Measurement of Geodetic Bases by Jäderin Invar Apparatus. Dehra Dun, 1912.

9. *Instructions for taking Magnetic Observations. *By J. Eccles, M. A.* Dehra Dūn, 1896,

10. **Rectangular Coordinates**—On a Simplification of the Computations relating to- *By J. Eccles, M. A.* Dehra Dūn, 1911. *Price Re 1 or 1s/4d.*

11. ***For Explorers**.—Notes on the use of Thermometers, Barometers and Hypsometers with Tables for the Computation of Heights. *By J. de Graaff Hunter, M. A.* Dehra Dūn, 1911.

D—MISCELLANEOUS PAPERS.

(*Obtainable from the Superintendent, Map Publication, 13, Wood Street, Calcutta*).

UNCLASSIFIED PAPERS.

Geography.

1. A Sketch of the Geography and Geology of the Himālaya Mountains and Tibet; in four parts. *By Colonel S. G. Burrard, R. E., F. R. S., Supdt., Trigonometrical Surveys, and Mr. H. H. Hayden, B. A., F. G. S., Supdt., Geological Survey of India.* Calcutta, 1907-08.

* For Departmental use only.

Digitized by Google

UNCLASSIFIED PAPERS—(*Continued*).

Geography—(*Continued*).

Part I.—The High Peaks of Asia.
" II.—The Principal Mountain Ranges of Asia.
" III.—The Rivers of the Himalaya and Tibet.
" IV.—The Geology of the Himalaya.
} *Price Rs. 2 or 2s/8d per part.*

2. *Report on the Identification and Nomenclature of the Himālayan Peaks as seen from Kātmāndu, Nepāl. Calcutta, 1904.

3. Routes in the Western Himālaya, Kashmír, etc. *By Lieut.-Colonel T. G. Montgomerie, R. E., F. R. S., F. R. G. S.* Third Edition. Revised and corrected. Dehra Dūn, 1909. (Out of print.)

Special Reports.

4. Report on the Recent Determination of the Longitude of Madras. Calcutta, 1897. (Out of print).

5. *Report on the Observation of the Total Solar Eclipse of 6th April 1875 at Camorta, Nicobar Islands. *By Colonel J. Waterhouse.* Calcutta, 1875. (Out of print).

6. *The Total Solar Eclipse, January 22, 1898. Dehra Dūn, 1898.

(1) Report on the observations at Dumraon.
(2) Report on the observations at Pulgaon.
(3) Report on the observations at Sahdol.

7. *Report on Local Attraction in India, 1893-94. *By Captain S. G. Burrard, R.E.* Calcutta, 1895. (Out of print.)

8. *Report on the Trigonometrical Results of the Earthquake in Assam. *By Captain S. G. Burrard.* Calcutta, 1898. (Out of print.)

9. *Notes on the Topographical Survey of the $\frac{1}{50,000}$ Sheets of Algeria by the Topographical Section of the "Service Geographique de l'Armēe". *By Captain W.M. Coldstream, R.E.* Calcutta, 1906.

10. *The Simla Estates Boundary Survey on the scale of 50 feet to 1 inch. *By Captain E.A. Tandy, R.E.* Calcutta, 1906.

Geodesy.

11. Notes on the Theory of Errors of Observation. *By J. Eccles, M.A.* Dehra Dūn, 1903. *Price As. 8 or 8d.*

12. *Note on a Change of the Axes of the Terrestrial Spheroid in relation to the Triangulation of the G.T. Survey of India. *By J. de Graaff Hunter, M.A.* Dehra Dūn. (Out of print.) Now incorporated in Professional Paper No. 16.

Projections.

13. On the projection used for the General Maps of India. Dehra Dūn, 1903. (Out of print).

14. *On the deformation resulting from the method of constructing the International Atlas of the World on the scale of one to one million. *By Ch Lallemand. Translated by J. Eccles, M.A.*, together with tables for the projection of 1/M Maps on the International system. Dehra Dūn, 1912. (Out of print).

Mapping.

15. *A Note on the different methods by which hills can be represented upon maps. *By Colonel S.G. Burrard, C.S.I., R.E., F.R.S., Surveyor General of India.* Simla, 1912.

16. *A Note on the representation of hills. *By Major C. L. Robertson, C.M.G., R.E.* Dehra Dūn, 1912.

17. *A Note on the representation of hills on the Maps of India. *By Major F. W. Pirrie, I.A.* Dehra Dūn, 1912.

18. *A consideration of the Contour intervals and Colour Scales best suited to Indian 1/M maps. *By Captain M. O'C. Tandy, R.E.* Calcutta, 1913.

PROFESSIONAL PAPERS—*Price Rupee 1 or 1s/4d per volume, except where otherwise stated.*

No. 1—**Projection**—On the Projection for a Map of India and adjacent Countries on the scale of 1 : 1,000,000. *By Colonel St. G. C. Gore, R.E.* Second Edition, Dehra Dūn, 1903.

No. 2—**Base Lines**—Method of measuring Geodetic Bases by means of Metallic Wires. *By M. Jäderin.* (Translated from Mēmoires Prēsentēs par Divers Savants ā l'Acadēmie des Sciences de l'Institut de France). Dehra Dūn, 1899. (Out of print.)

* For Departmental use only.

Digitized by Google

PROFESSIONAL PAPERS—(*Continued*).

No. 3—**Base Lines**—Method of measuring Geodetic Bases by means of Colby's Compensated Bars. Compiled *by Lieutenant H. McC. Cowie, R. E.* Dehra Dūn, 1900. (Out of print.)

No. 4—**Spirit-levels**—Notes on the Calibration of Levels. *By Lieutenant E. A. Tandy, R. E.* Dehra Dūn, 1900. (Out of print.)

No. 5—**Geodesy**—The Attraction of the Himālaya Mountains upon the Plumb-Line in India. Considerations of recent data. *By Major S. G. Burrard, R. E.* Second Edition. Dehra Dūn, 1901. *Price Rs. 2 or 2s/8d.*

No. 6—**Base Lines**—Account of a Determination of the Co-efficients of Expansion of the Wires of the Jäderin Base-Line Apparatus. *By Captain G. P. Lenox-Conyngham, R. E.* Dehra Dūn, 1902.

No. 7—**Miscellaneous**. Calcutta, 1903.

(1) On the values of Longitude employed in maps of the Survey of India.
(2) Levelling across the Ganges at Dāmukdia.
(3) Experiment to test the increase in the length of a Levelling Staff due to moisture and temperature.
(4) Description of a Sun-dial designed for use with tide gauges.
(5) Nickel-steel alloys and their application to Geodesy. (Translated from the French.)
(6) Theory of electric projectors. (Translated from the French.)

No. 8—**Magnetic**—Experiments made to determine the temperature co-efficients of Watson's Magnetographs. *By Captain H. A. Denholm Fraser, R. E.* Calcutta 1905.

No. 9—**Geodesy**—An Account of the Scientific work of the Survey of India and a Comparison of its progress with that of Foreign Surveys. *Prepared for the use of the Survey Committee, 1905 By Lieutenant-Colonel S. G. Burrard, R. E., F. R. S.* Calcutta, 1905.

No. 10—**Pendulums**—The Pendulum Operations in India, 1903-1907. *By Major G. P. Lenox-Conyngham, R. E.* Dehra Dūn, 1908. *Price Rs. 2-8 or 3s/4d.*

No. 11—**Refraction**—Observations of Atmospheric Refraction, 1905-09. *By H. G. Shaw, Survey of India.* Dehra Dūn, 1911. (Out of print.)

No. 12—**Geodesy**—On the Origin of the Himālaya Mountains. *By Colonel S. G. Burrard C. S. I., R. E., F. R. S.* Calcutta, 1912.

No. 13—**Isostasy**—Investigation of the Theory of Isostasy in India. *By Major H. L. Crosthwait, R.E.* Dehra Dūn, 1912.

No. 14—**Refraction**—Formulæ for Atmoshpheric Refraction and their application to Terrestrial Refraction and Geodesy. *By J. de Graaff Hunter, M. A.* Dehra Dūn, 1913. *Price Rs. 2 or 2s/8d.*

No. 15—**Pendulums**—The Pendulum Operations in India and Burma, 1908-13, *By Captain H. J. Couchman, R. E.* Dehra Dūn, 1915. *Price Rs. 2-8 or 3s/4d.*

No. 16—**Geodesy**—The Earth's Axes and Triangulation. *By J. de Graaff Hunter, M.A. (at press).*

DEPARTMENTAL PAPERS SERIES. (*For departmental use only.*)

No. 1—**Type**—A consideration of the most suitable forms of type for use on maps. *By Captain M. O'C. Tandy, R. E.* Dehra Dūn, 1913.

No. 2—**Symbols**—A review of the Boundary Symbols used on the maps of various countries. *By Captain M. O'C. Tandy, R. E.* Dehra Dūn, 1913.

No. 3—**Maps**—Extract from "The New Map of Italy, Scale 1: 100,000." *By Luigi Giannitrapani.* Translated from the Italian *by Major W. M. Coldstream, R.E.* Dehra Dūn, 1913.

No. 4—**Town Surveys**—A report on the practice of Town Surveys in the United Kingdom and its application to India. *By Major C. L. Robertson, C.M.G., R.E.* Dehra Dūn, 1913.

No. 5—**Stereo-plotter**—The Thompson Stereo-plotter and its use, with notes on the field work. *By Lieutenant K. Mason, R. E.* Dehra Dūn, 1913.

No. 6—**Levelling**—Levelling of High Precision. *By Ch. Lallemand.* Translated from the French *by J. de Graaff Hunter, M.A.* Dehra Dūn, 1914.

No. 7—**Standard Bars**—Bar Comparisons of 1907 and 1908. *By Major H. McC Cowie, R.E.* Dehra Dūn, 1915.

No. 8—**Helio-zincography**—Report on Rubber Off-set Flat bed Machine Printing. *By Captain S. W. Sackville Hamilton, R.E.* Calcutta, 1915.

Digitized by Google

PROFESSIONAL FORMS.

A large number of forms for the record and reduction of Survey Operations are stocked at Dehra. A list of these can be obtained from the Superintendent of the Trigonometrical Survey, Dehra Dūn, U. P.

PUBLICATIONS OF THE ROYAL SOCIETY.

(*Obtainable from Messrs. Dulau & Co., 37, Soho Square, London, W., or Messrs. Harrison & Sons, St. Martin's Lane, London, or the Royal Society at Burlington House, London.*)

1. Philosophical Transactions, Series A, Volume 186, 1895. India's Contribution to Geodesy, *by General J. T. Walker, R.E., C.B., F.R.S., LL.D.*
2. Philosophical Transactions, Series A, Volume 205, pages 289-318, 1905. On the Intensity and Direction of the Force of Gravity in India, *by Lieutenant-Colonel S.G. Burrard, R.E., F.R.S.*
3. Proceedings, Series A, Volume 90, pages 32-40, 1914. On the effect of the Gangetic Alluvium on the Plumb-Line in Northern India, *by R. D. Oldham, F.R.S.*
4. Proceedings, Series A, Volume 91, pages 220-238, 1915. On the origin of the Indo-Gangetic trough, commonly called the Himalayan Foredeep, *by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S.*

AGENTS FOR THE SALE OF INDIAN OFFICIAL PUBLICATIONS.

LONDON.

A. Constable & Co., 10, Orange Street, Leicester Square, W.C.

P. S. King & Son, 2 and 4, Great Smith Street, Westminster, S.W.

Kegan Paul, Trench, Trubner & Co., 68, Carter Lane, E.C.

B. Quaritch, 11, Grafton Street, New Bond Street, W.

Henry S. King & Co., 65, Cornhill, E.C.

Grindlay & Co., 54, Parliament Street, S.W.

T. Fisher Unwin, Ltd., 1, Adelphi Terrace, W.C.

W. Thacker & Co., 2, Creed Lane, Ludgate Hill, E.C.

Luzac & Co., 46, Great Russell Street, W.C.

Edward Stanford, Ltd. (*for maps only*), 12-14, Long Acre, W.C.

EDINBURGH.

Oliver and Boyd, Tweeddale Court.

DUBLIN.

E. Ponsonby, Ltd., 116, Grafton Street.

OXFORD.

B. H. Blackwell, 50 and 51, Broad Street.

CAMBRIDGE.

Deighton, Bell & Co., Ltd., Trinity Street.

ON THE CONTINENT.

Ernest Leroux, Rue Bonaparte, Paris, France.

Martinus Nijhoff, The Hague, Holland.

INDIA.

Thacker, Spink & Co., No. 3, Esplanade, East, Calcutta, and Simla.

Newman & Co., No. 4, Dalhousie Square, Calcutta.

Lal Chand & Sons, No. 76, Lower Circular Road, Calcutta.

The Secretary, Indian School Supply Depot, No. 309, Bow Bazar Street, Calcutta, and Dacca.

Rai Sahib M. Gulab Singh & Sons, Lahore.

Thacker & Co., Ltd., Bombay.

D. B. Taraporevala, Sons & Co., Bombay.

Higginbotham & Co., Madras.

Proprietor, Mafasilite Printing Works, Mussoorie.

Superintendent, American Baptist Mission Press, 70, Merchant Street, Rangoon.

Cockburn's Agency, Srīnagar.

Burman & Co., Muzaffarpur.

Digitized by Google

Digitized by Google

Triangulation pamphlets and charts published up to 30th September 1916, with years of publication.

	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	
A								d 1912	a 1916	f		d 1911			S				a c 1916	a 1916	f	d 1911	a c 1916	a c 1916	a c 1916	a 1916	S	S			d 1911				a c 1915	a c 1916	b 1916			d 1911			A
B								d 1912	a 1916	f		d 1913			S				a c 1916	a 1916	f		a c 1916	a c 1916	a 1916	a 1916	S	S			d 1911			a c 1916	a c 1916	a c 1916	a c 1916			d 1911		d 1913	B
C								d 1912	a 1916	f		a c 1915	a c 1915		S	d 1911			a c 1916	S	d 1911		a c 1916	a c 1916	a 1916	S	S	S		d 1911	d 1911				a c 1916	a c 1916	a c 1916			d 1911			C
D							d 1912	d 1912	a 1916	S	d 1912			S	S	d 1912			a c 1916	S	d 1911	d 1912	a c 1916	a c 1916	d 1916	S	S	S		d 1911					a c 1916	a c 1915	a c 1916		d 1912	f	d 1912		D
E								d 1912	a 1916	f		d 1911			S				a c 1916	a 1916	f	d 1911	a c 1916	a c 1916	a 1916	a 1916	a 1916	S			d 1911		d 1911	a c 1916		a 1916	a 1916			d 1911			E
F								d 1912	a 1916	f		d 1913			S			d 1911	a c 1916	a 1916	f	d 1911	a c 1916	a c 1916	a 1916	a 1916	S	S			d 1911			a c 1915	a c 1915	a 1916	a c 1916			d 1911			F
G								d 1912	a 1916	f	d 1912	d 1914			S				a c 1916	a 1916	d 1911	d 1913	a c 1916	a c 1916	a 1916	a 1916	S	S			d 1911			a c 1915	a c 1916	d 1907	a c 1915			d 1911			G
H								d 1912	a 1916	S	d 1912	d 1911		S	S	d 1911	bc 1916		d 1912	S	d 1911		a c 1916	a c 1916	a 1916	a 1916	S	S							a c 1916	a c 1915	a c 1916		d 1912	d 1911			H
I								d 1912	a 1916			d 1911			S			bc 1915	a c 1916	a 1916	d 1911	d 1911	a c 1916	a c 1916	a 1916	a 1916	a 1916	S			d 1911		d 1911			a c 1916	a c 1916			d 1911	f		I
J								d 1912	a 1916	f		d 1913			S				a c 1916	a 1916	d 1911	d 1911	a c 1916	a c 1916	a 1916	a 1916	a 1916	S			d 1911			a c 1916		a c 1916	a c 1916			d 1912	d 1912		J
K								d 1912	a 1916	f	d 1912	d 1914		d 1914	S		b 1916		d 1912	a 1916	a c 1915	d 1911	a c 1916	a c 1916	a 1916	a 1916	a 1916	S			d 1911				a c 1916	a 1916	a c 1916			d 1911	d 1912		K
L								d 1912	a 1916	S	d 1912	d 1911			S		bc 1916		d 1914	a 1916	a c 1915	d 1911	a c 1916	a c 1916	a 1916	a 1916	a c 1916	S		d 1911	d 1911	d 1912	a c 1915		a c 1916	a c 1915	a c 1915		d 1912	d 1911			L
M		d 1912						d 1912	f	f		d 1911			a 1916				a c 1916	a 1916	d 1911	d 1911	a 1916	a c 1916	a 1916	a c 1916	a 1916	a c 1916			d 1911	d 1911			d 1912	a c 1916	a c 1916			d 1911	f		M
N								d 1912	a 1916	f		d 1914			S		d 1912		a c 1916	a 1916	d 1916	d 1911	a 1916	a c 1916	a c 1916	a c 1915	a 1916	d 1913			d 1911	d 1912	d 1912	a c 1915		a c 1916	a 1916			d 1911	d 1913		N
O		d 1912						d 1912	a 1916	f					S		a c 1916		a c 1916	a 1916	a c 1915	d 1911	a c 1916	a c 1916	a 1916	a 1916	a c 1916	S			d 1911				a 1916	a c 1915	a c 1915			d 1911	d 1912		O
P	d 1911	d 1912					d 1913	d 1912	a 1916	S	d 1912	d 1911			S	d 1911	d 1913		a c 1916	a 1916	d 191	d 1911	a c 1916	a c 1916	a 1916	a 1916	a 1915	S		d 1911	d 1911	d 1911	d 1914	d 1913	a 1916	a c 1916	f		d 1912	f			P

	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	
A	b c 1915		a c 1916				d 1912	f														S	S		S							S	S											A
B			a c 1915					f		a 1916												S	S		S							S	S											B
C			a c 1915					a c 1916			S			d 1913	d 1912							S			S							S	S											C
D			a c 1915					a c 1916			S				d 1912	S						S			S							S	S							d 1913				D
E			a c 1916					f								d 1912							S										S											E
F			S					f		a 1916	S													S							d 1913													F
G			S					a c 1916			S			d 1913								S		S	S														d 1911					G
H			S					a c 1916			S					S						S			S							S	S											H
I			S					f														d 1913		S	S																			I
J			S					f			S									a c 1915			S	S	S																			J
K			S					a c 1916			S			d 1913										S	S																			K
L			S					a c 1916	a c 1916		S			d 1913		S					d 1913		S	S	S																			L
M			S					f			S				b c 1916									S	S						b c 1916													M
N	a 1916		S					f			S				b c 1915								S	S	S					d 1913														N
O	a 1916		S					a c 1916			S			d 1913									S	S	S																			O
P		S	S					a c 1916	a c 1916		S			d 1913	d 1912	S							S	S	S																			P

a Pamphlet with G.T. data available at Trigonometrical Survey Office. *b* Pamphlet with G.T., if any, and Topo. data received from parties. *c* Data with chart.
d Data published in the old style (chart form). *f* No data available at Trigonometrical Survey Office. *S* Area falling in the sea.

Digitized by Google

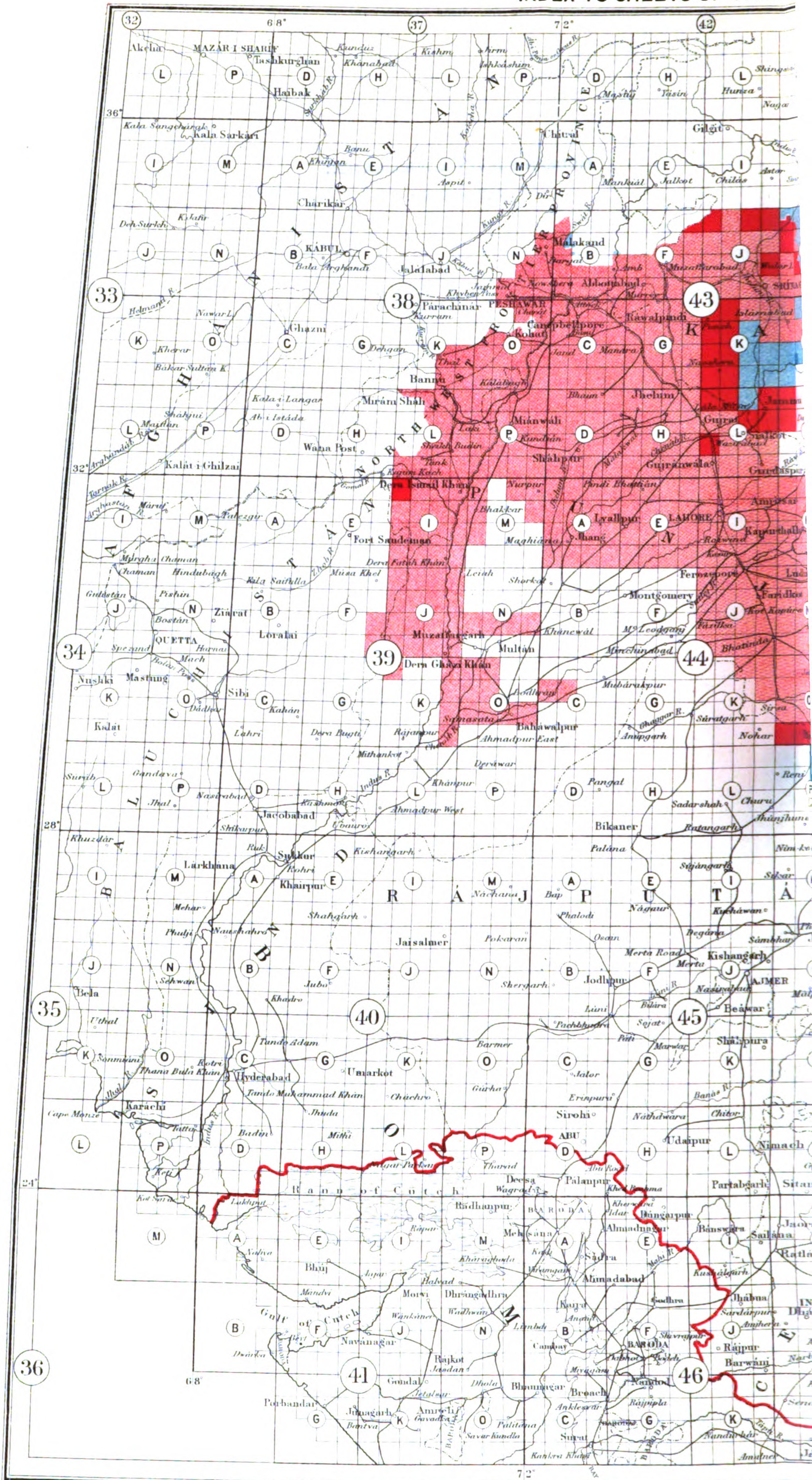
Digitized by Google

MODERN SURVEY & PUBLICATION

(Northern Circle).

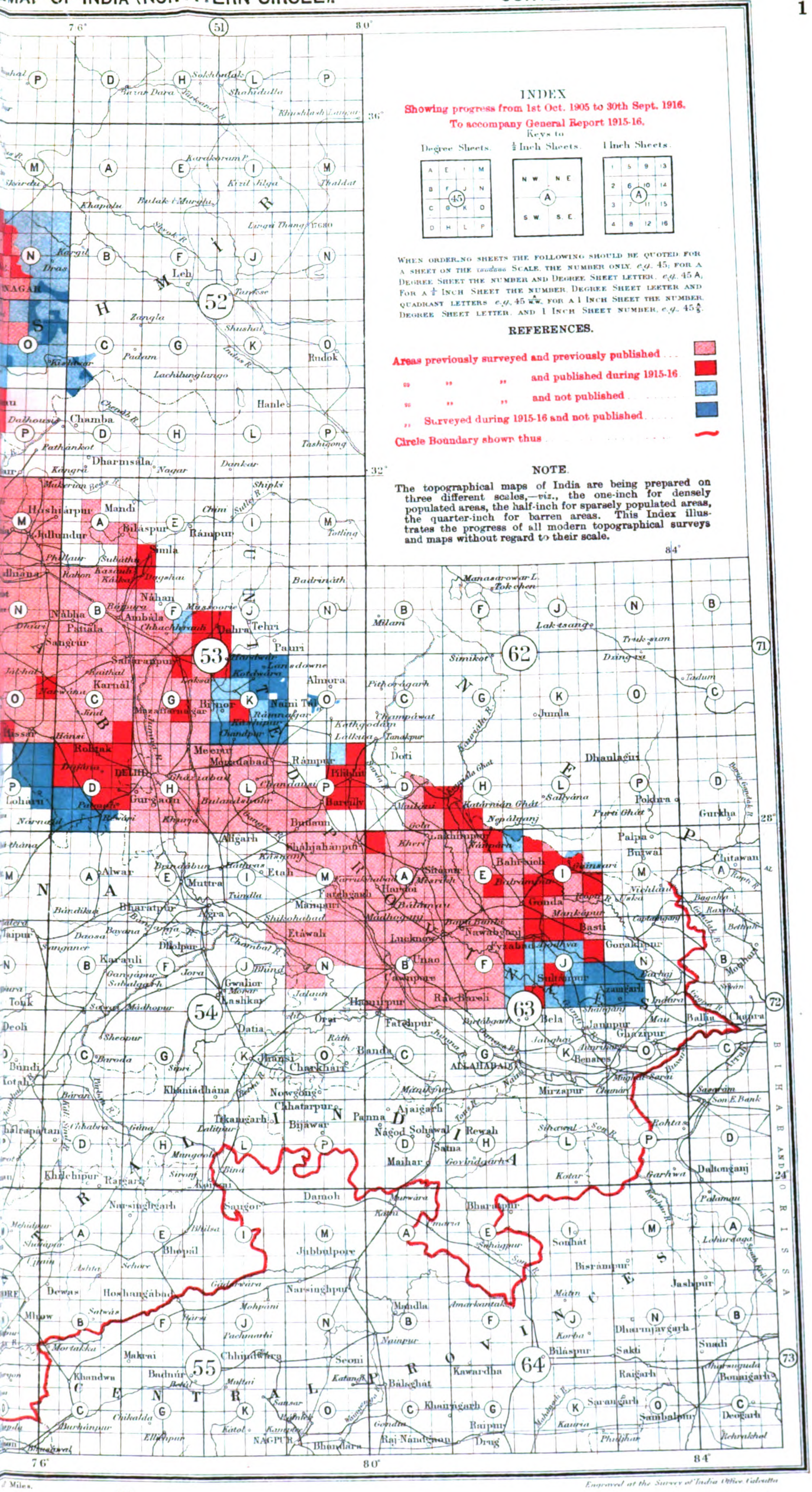
Digitized by Google

INDEX TO SHEETS OF THE MA



Reg. No. 3430 D., 16

Digitized by Google



Engraved at the Survey of India Office Calcutta

Litho., S. I. O., Calcutta.

Digitized by Google

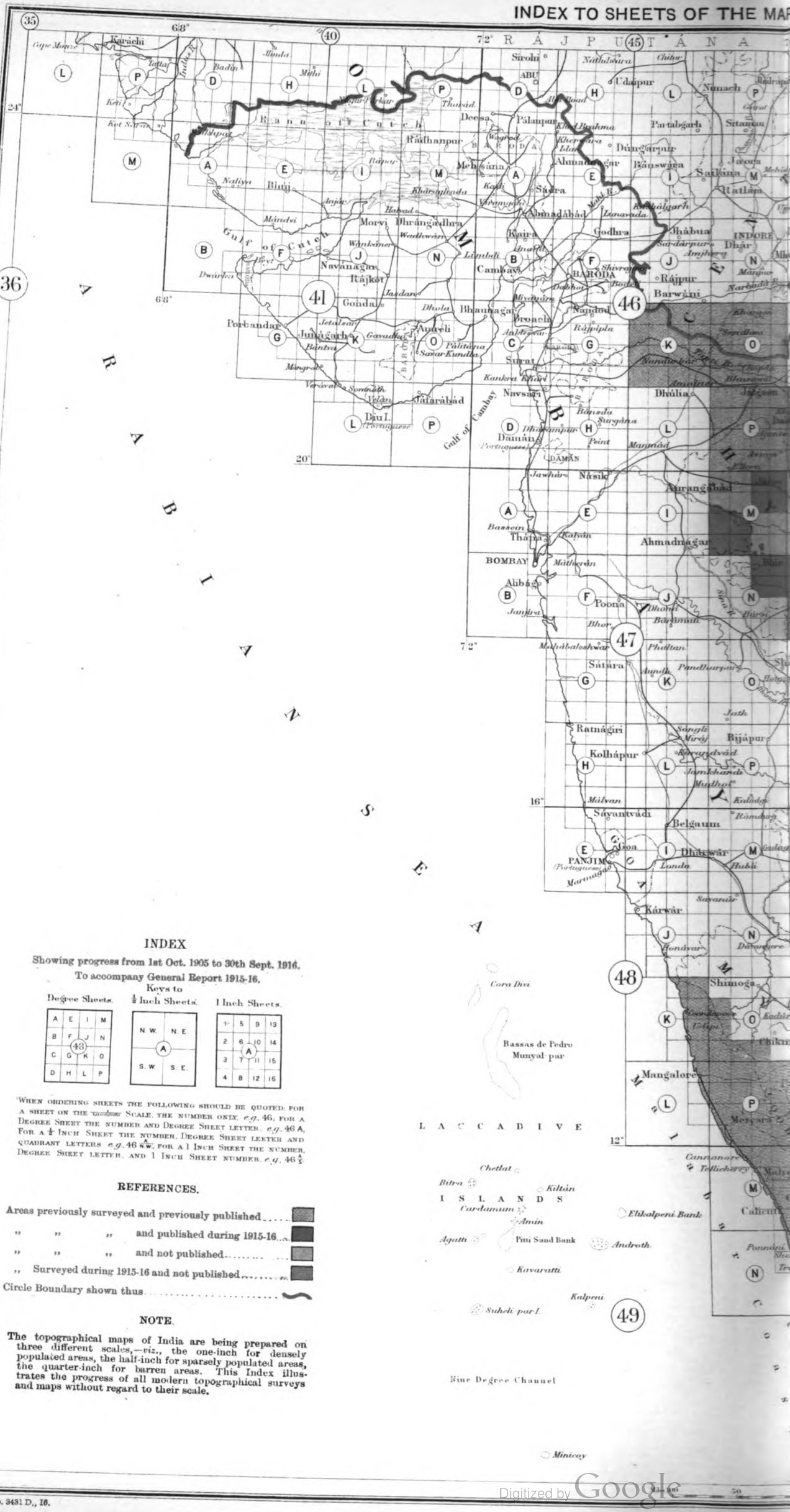
Digitized by Google

SURVEY & PUBLICATION

(Southern Circle).

Digitized by Google

INDEX TO SHEETS OF THE MAP



INDEX

Showing progress from 1st Oct. 1905 to 30th Sept. 1916.

To accompany General Report 1915-16.

Keys to

Degree Sheets. ½ Inch Sheets. 1 Inch Sheets.

A	E	I	M
B	F	J	N
C	G	K	O
D	H	L	P

(43)

N. W.	N. E.
S. W.	S. E.

(A)

1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16

(A)

When ordering sheets the following should be quoted: for a sheet on the [illegible] scale, the number only, *e.g.* 46, for a Degree Sheet the number and Degree Sheet letter, *e.g.* 46 A, For a ½ Inch Sheet the number, Degree Sheet letter and quadrant letters *e.g.* 46 $^{A}_{N.W.}$, for a 1 Inch Sheet the number, Degree Sheet letter, and 1 Inch Sheet number, *e.g.* 46 $^{A}_{5}$.

REFERENCES.

Areas previously surveyed and previously published.....

" " " and published during 1915-16...

" " " and not published.....

" Surveyed during 1915-16 and not published.....

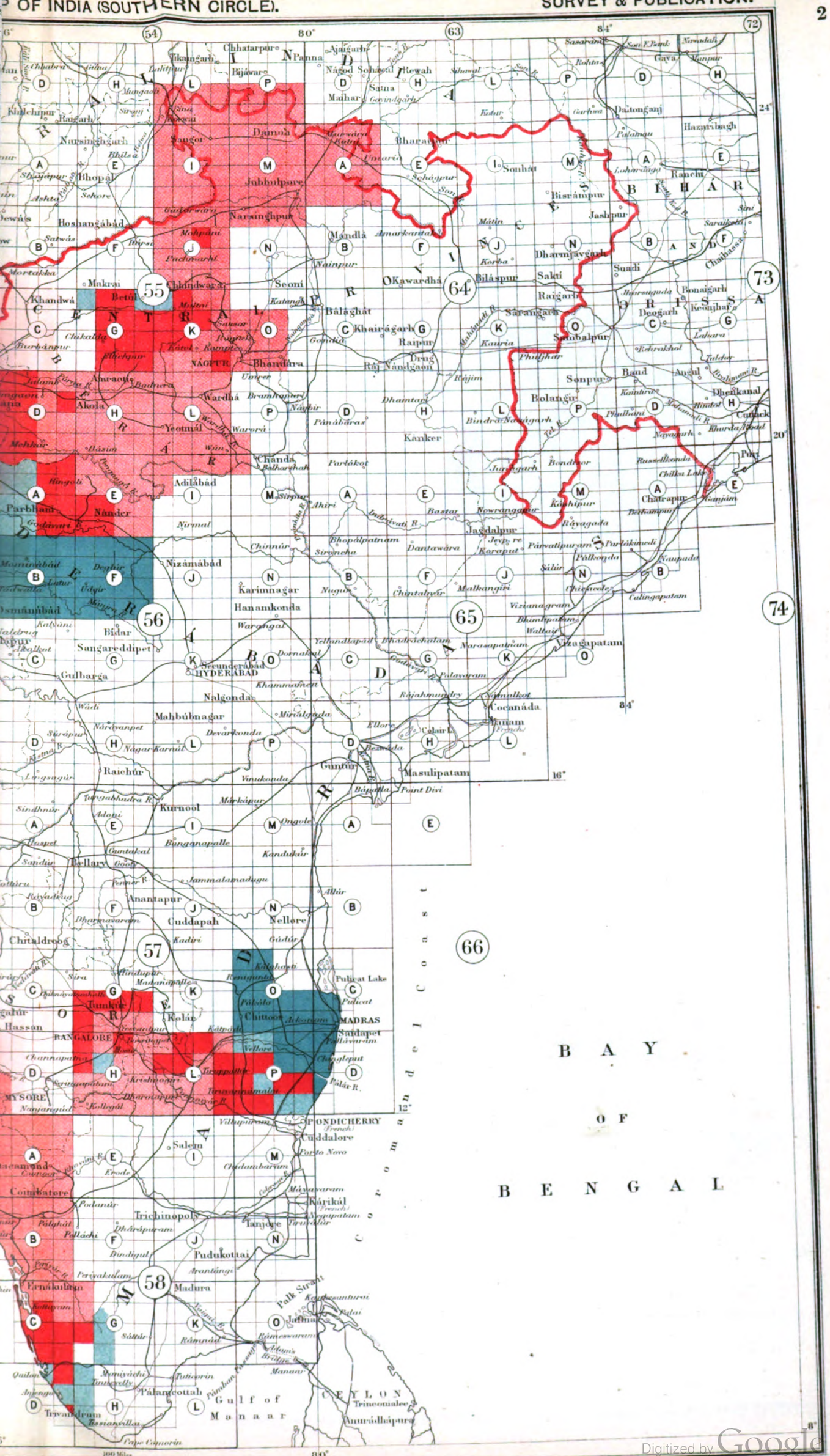
Circle Boundary shown thus.....

NOTE.

The topographical maps of India are being prepared on three different scales,—*viz.*, the one-inch for densely populated areas, the half-inch for sparsely populated areas, the quarter-inch for barren areas. This Index illustrates the progress of all modern topographical surveys and maps without regard to their scale.

Reg. No. 3431 D., 16.

Digitized by Google



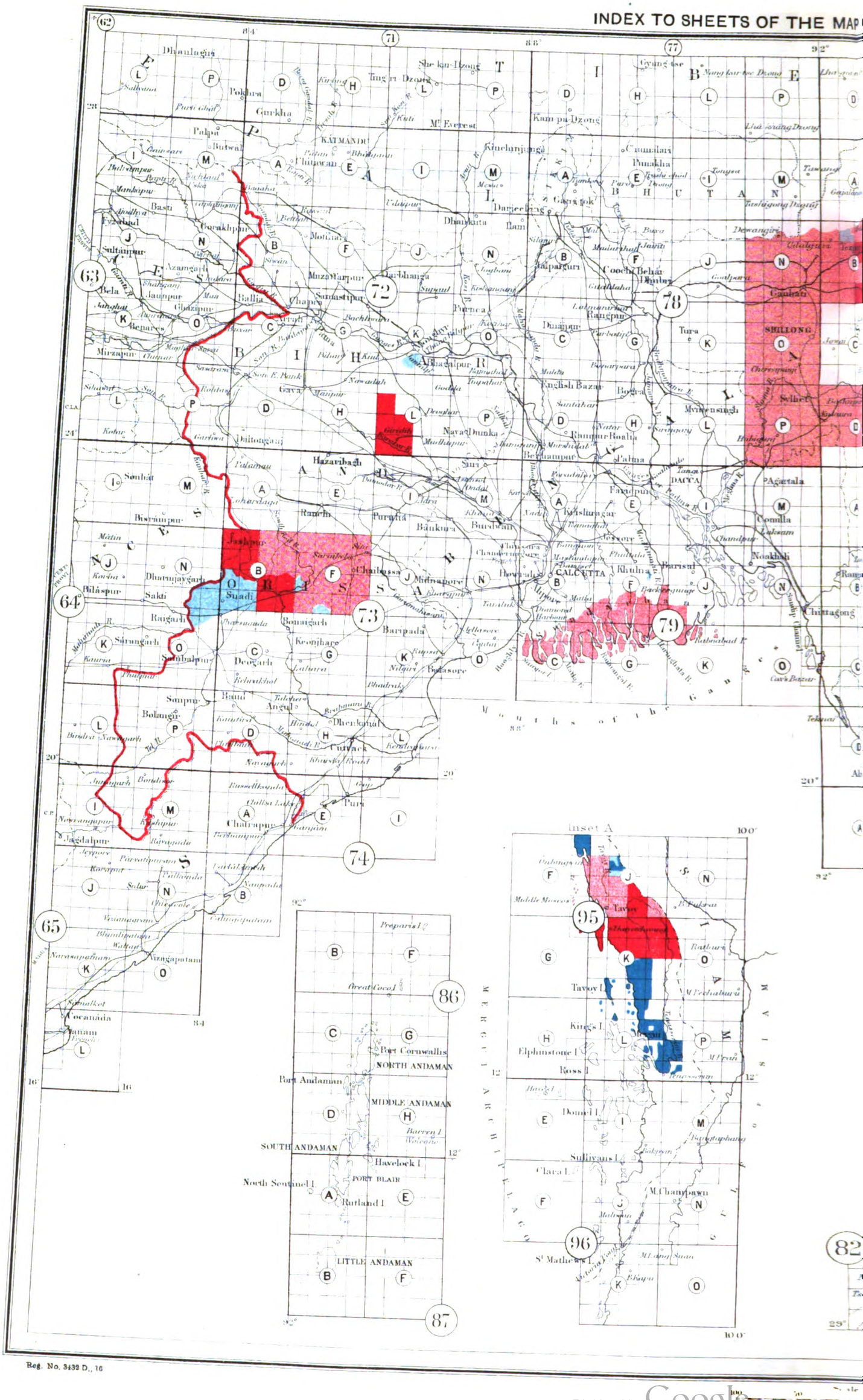
Digitized by Google

Digitized by Google

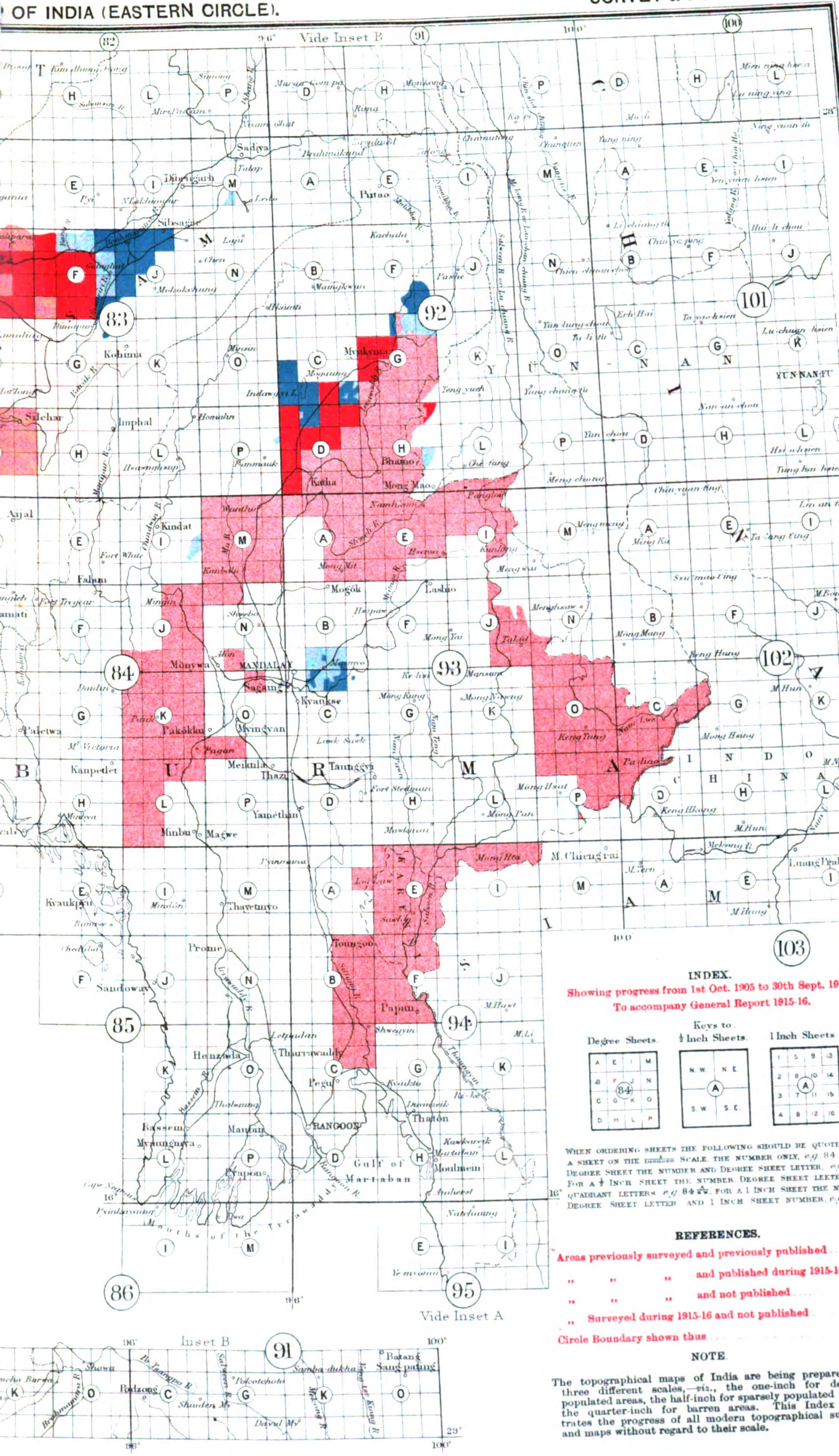
MODERN SURVEY AND PUBLICATION

(Eastern Circle).

Digitized by Google



Digitized by Google



INDEX.

Showing progress from 1st Oct. 1905 to 30th Sept. 1916.

To accompany General Report 1915-16.

Keys to

Degree Sheets.	½ Inch Sheets.	1 Inch Sheets.
A E I M / B F J N / C G K O / D H L P (84)	N.W. N.E. / S.W. S.E. (A)	1 5 9 13 / 2 6 10 14 / 3 7 11 15 / 4 8 12 16 (A)

WHEN ORDERING SHEETS THE FOLLOWING SHOULD BE QUOTED FOR A SHEET ON THE $\frac{1}{1000000}$ SCALE THE NUMBER ONLY, *e.g.* 84 FOR A DEGREE SHEET THE NUMBER AND DEGREE SHEET LETTER, *e.g.* 84 A; FOR A ½ INCH SHEET THE NUMBER, DEGREE SHEET LETTER AND QUADRANT LETTERS *e.g.* 84 $\frac{A}{N.W.}$ FOR A 1 INCH SHEET THE NUMBER, DEGREE SHEET LETTER AND 1 INCH SHEET NUMBER, *e.g.* 84 $\frac{A}{5}$

REFERENCES.

Areas previously surveyed and previously published

" " " and published during 1915-16.

" " " and not published

" Surveyed during 1915-16 and not published

Circle Boundary shown thus

NOTE.

The topographical maps of India are being prepared on three different scales,—*viz.*, the one-inch for densely populated areas, the half-inch for sparsely populated areas, the quarter-inch for barren areas. This Index illustrates the progress of all modern topographical surveys and maps without regard to their scale.

Litho., S. I. O., Calcutta.

Digitized by Google

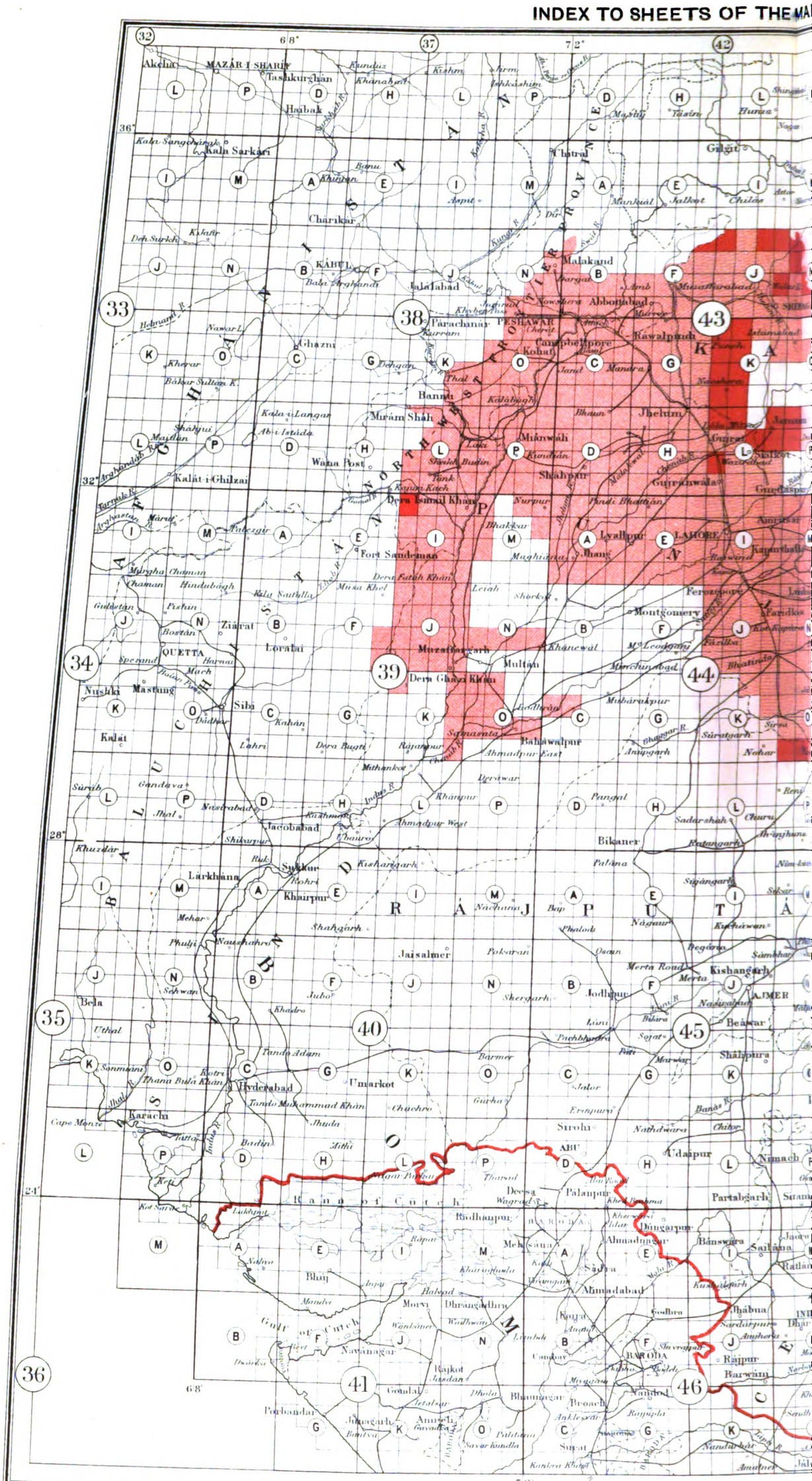
Digitized by Google

MODERN ONE-INCH PUBLICATION

(Northern Circle).

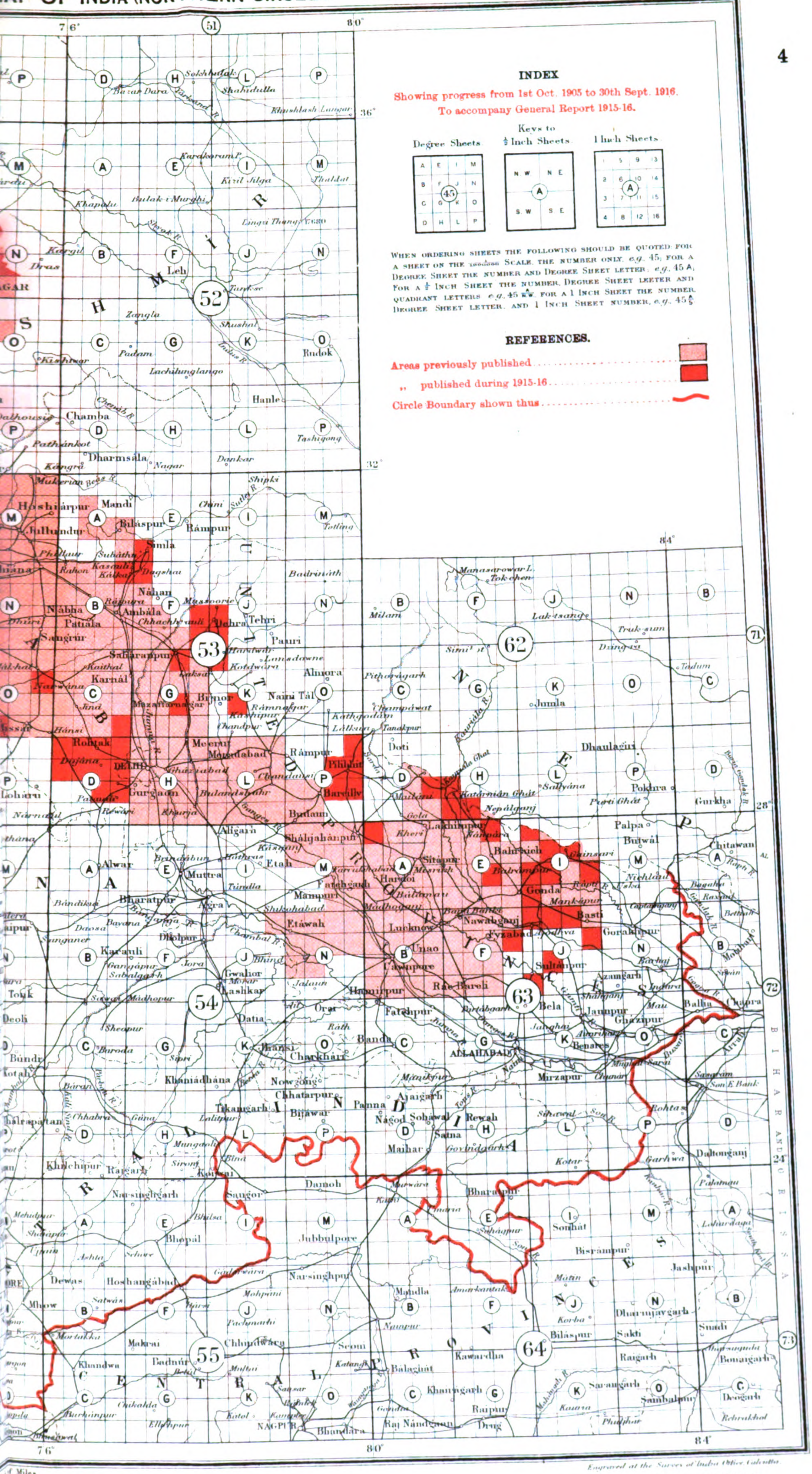
Digitized by Google

INDEX TO SHEETS OF THE MA



Digitized by Google

MAP OF INDIA (NORTHERN CIRCLE). PUBLICATION OF MODERN ONE-INCH SERIES.



Digitized by Google

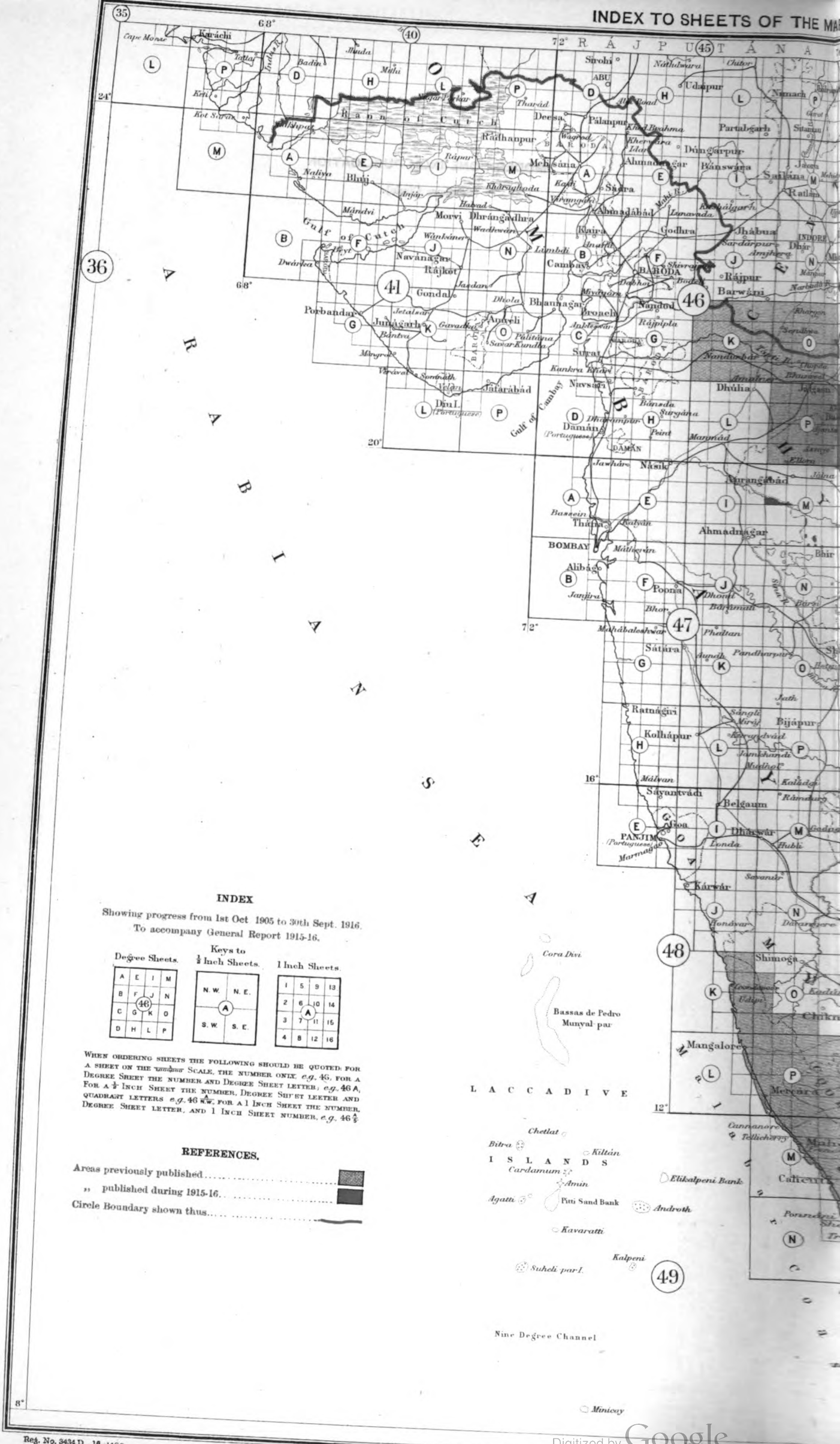
Digitized by Google

MODERN ONE-INCH PUBLICATION

(Southern Circle).

Digitized by Google

INDEX TO SHEETS OF THE MAP



INDEX

Showing progress from 1st Oct 1905 to 30th Sept. 1916.
To accompany General Report 1915-16.

Degree Sheets.

A	E	I	M
B	F	J	N
C	G	K	O
D	H	L	P

(46)

Keys to ½ Inch Sheets.

N.W.	N.E.
S.W.	S.E.

(A)

1 Inch Sheets.

1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16

(A)

When ordering sheets the following should be quoted: For a sheet on the 1/2000000 Scale, the number only, *e.g.* 46; for a Degree Sheet the number and Degree Sheet letter, *e.g.* 46 A; for a ½ Inch Sheet the number, Degree Sheet letter and quadrant letters *e.g.* 46 $\frac{A}{N.W.}$; for a 1 Inch Sheet the number, Degree Sheet letter, and 1 Inch Sheet number, *e.g.* 46 $\frac{A}{6}$.

REFERENCES.

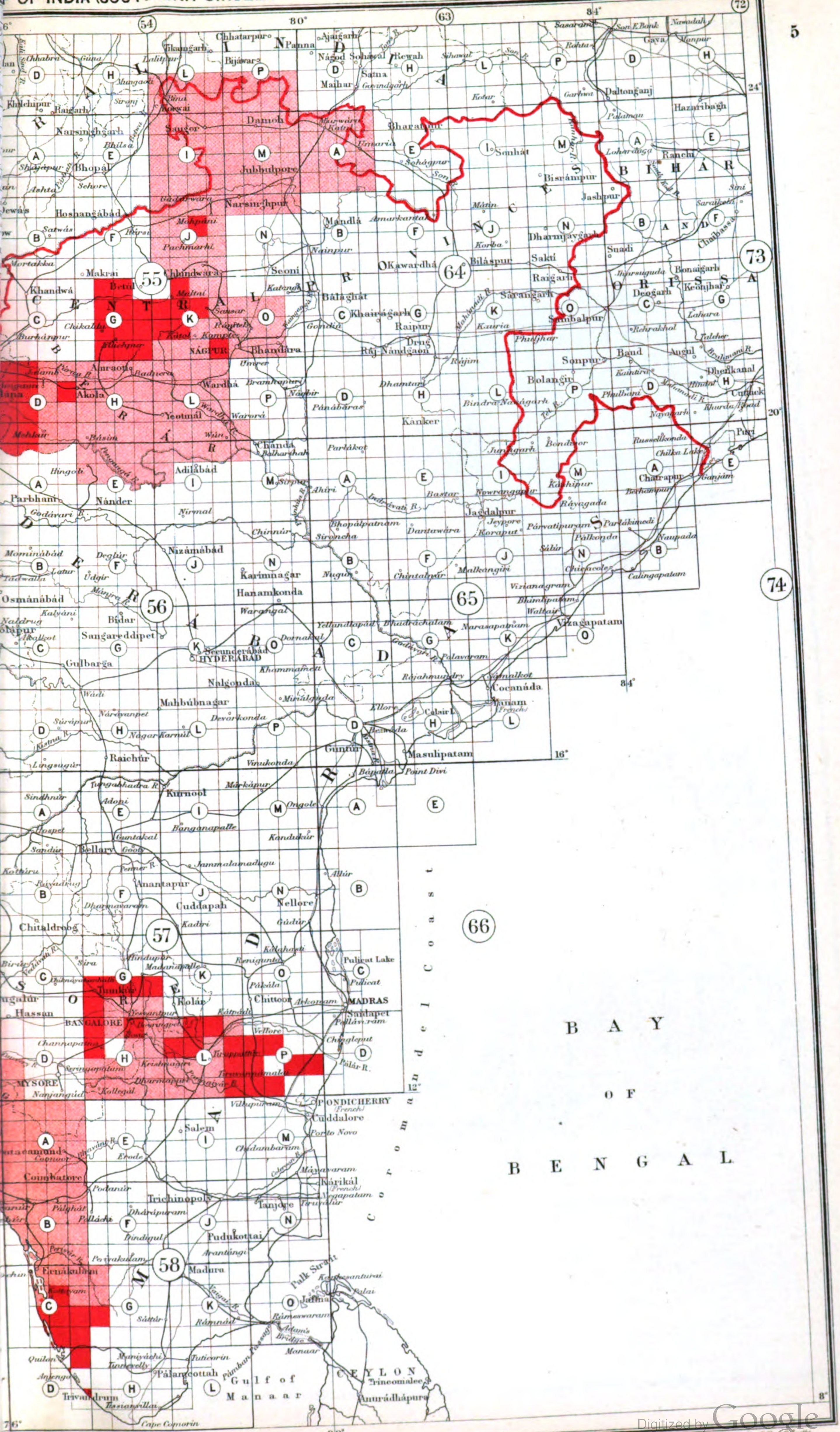
Areas previously published.....

" published during 1915-16.....

Circle Boundary shown thus.....

Reg. No. 3434 D., 16.-1400

Digitized by Google



Digitized by Google

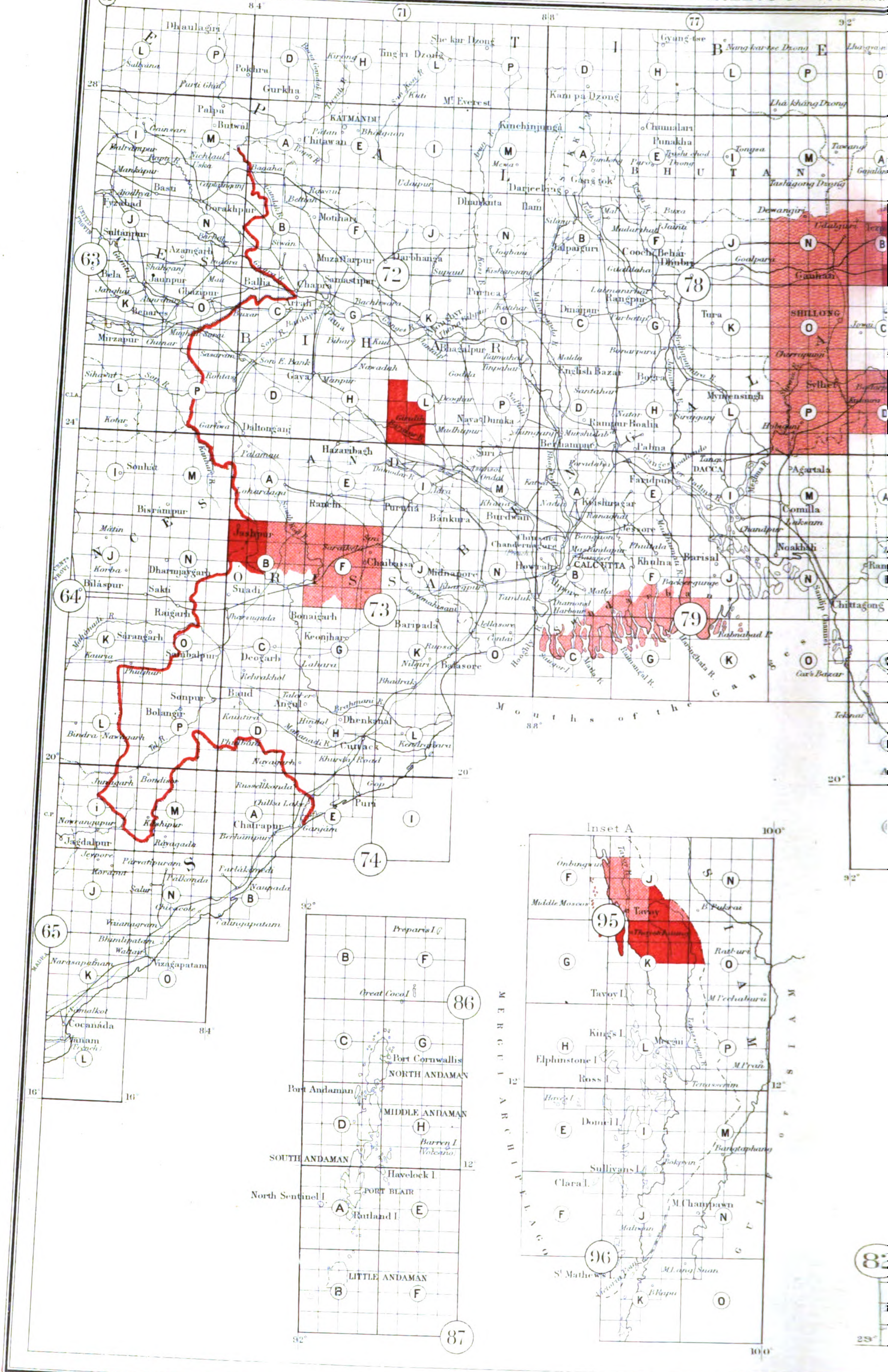
Digitized by Google

MODERN ONE-INCH PUBLICATION

(Eastern Circle).

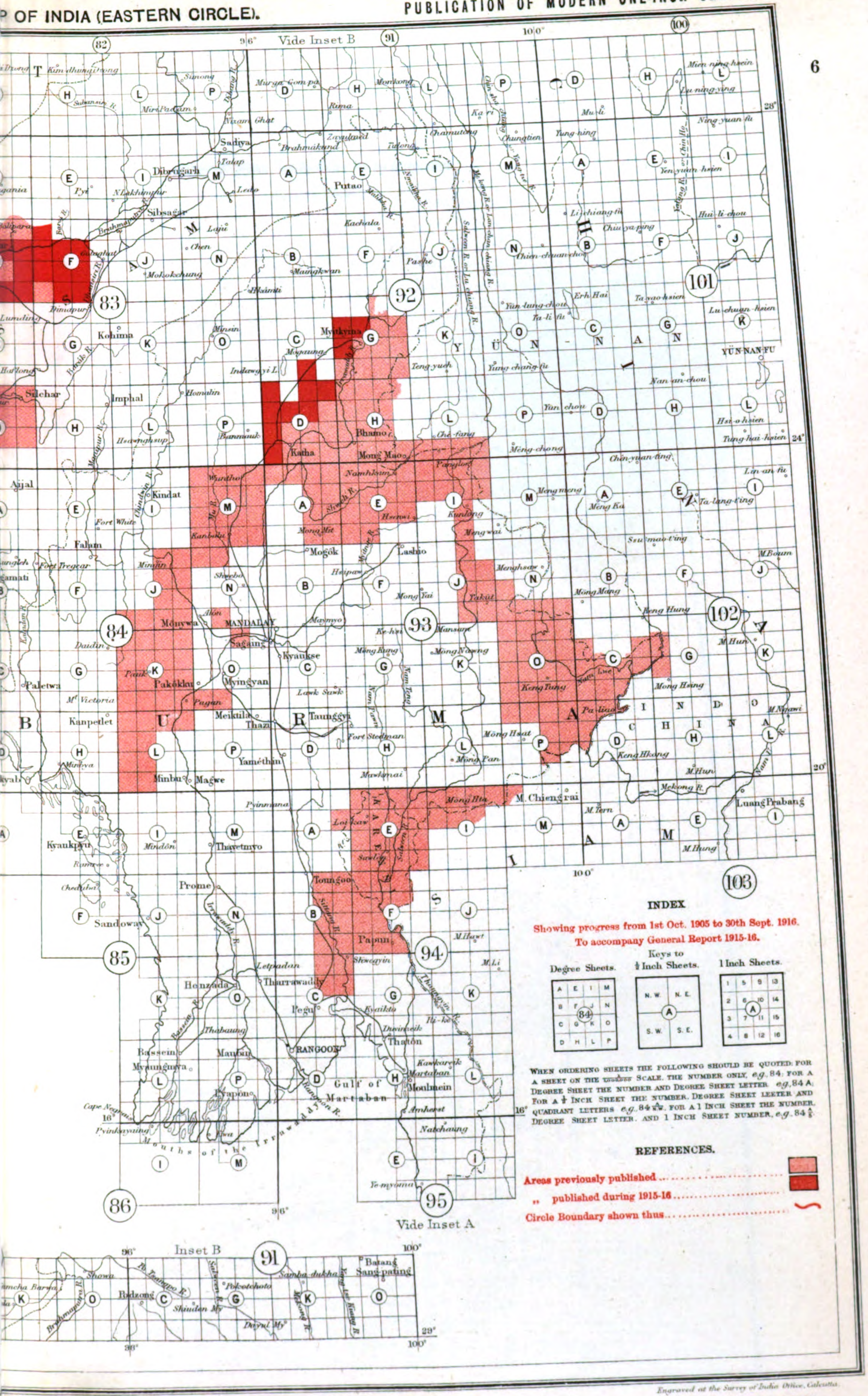
Digitized by Google

INDEX TO SHEETS OF THE MAP



Reg. No. 3435 D., 16.-1400.

Digitized by Google



Digitized by Google

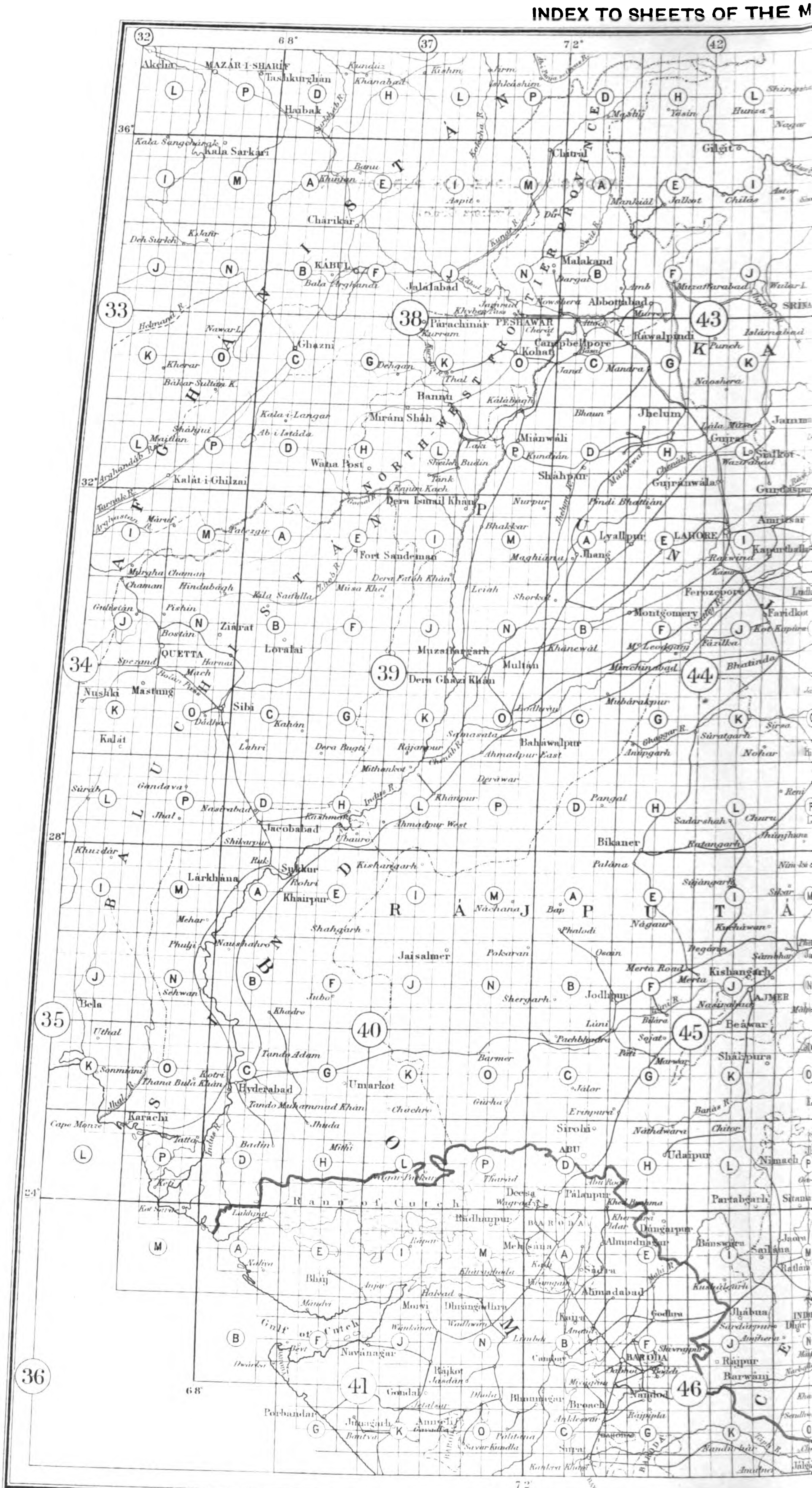
Digitized by Google

PROVISIONAL ONE-INCH PUBLICATION

(Northern Circle).

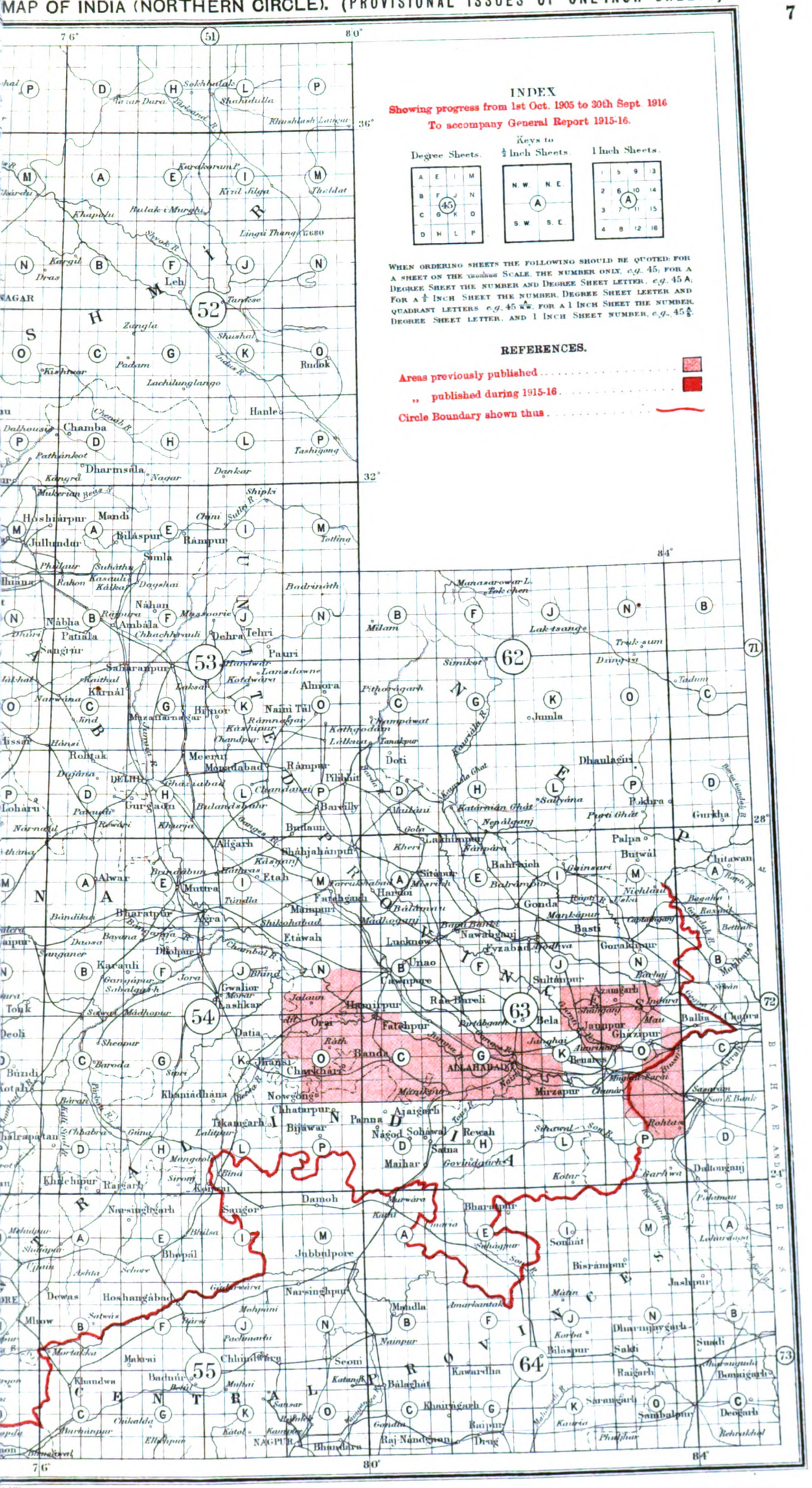
Digitized by Google

INDEX TO SHEETS OF THE M



Reg. No. 3436 D., 16.

Digitized by Google



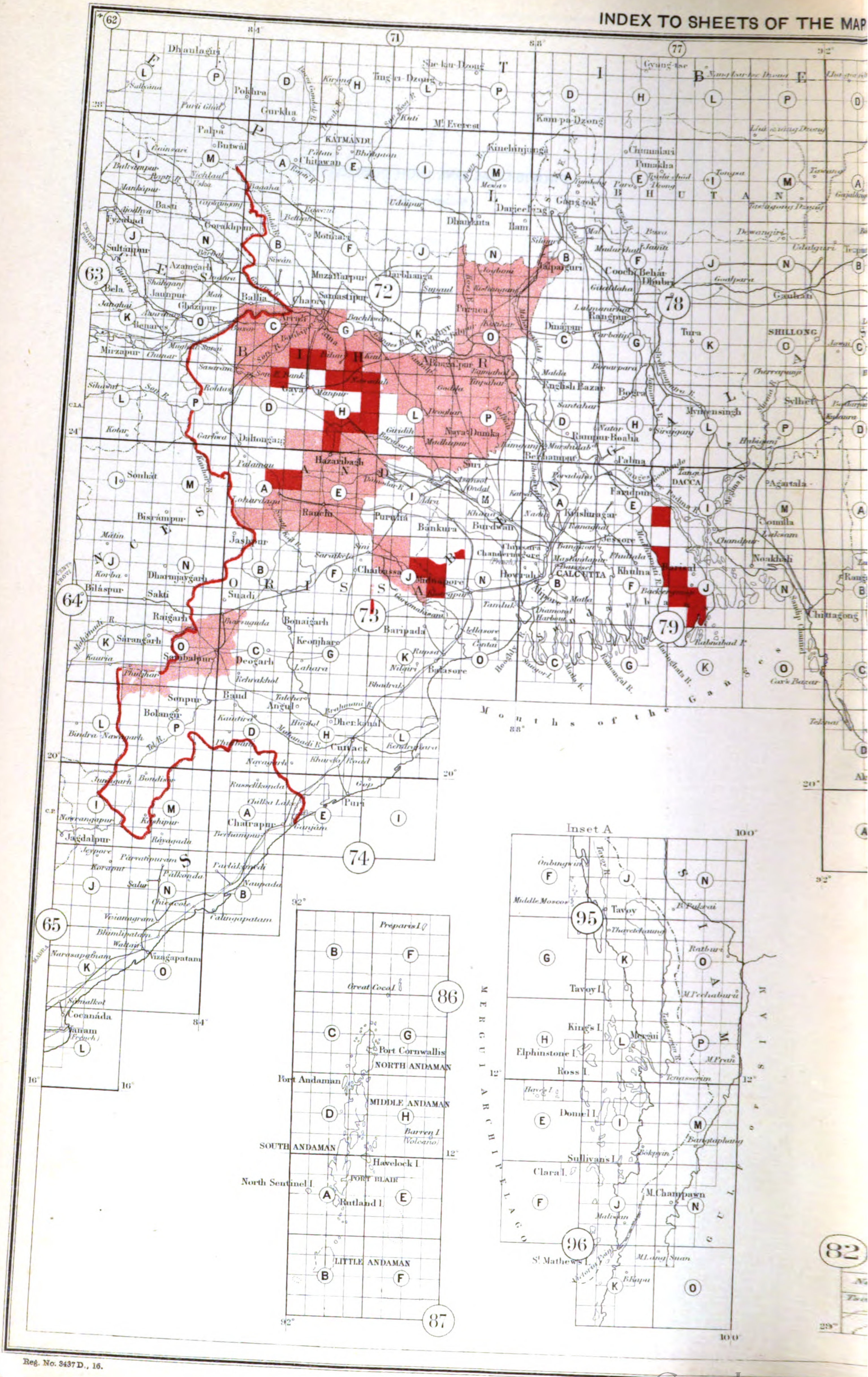
Digitized by Google

Digitized by Google

PROVISIONAL ONE-INCH PUBLICATION

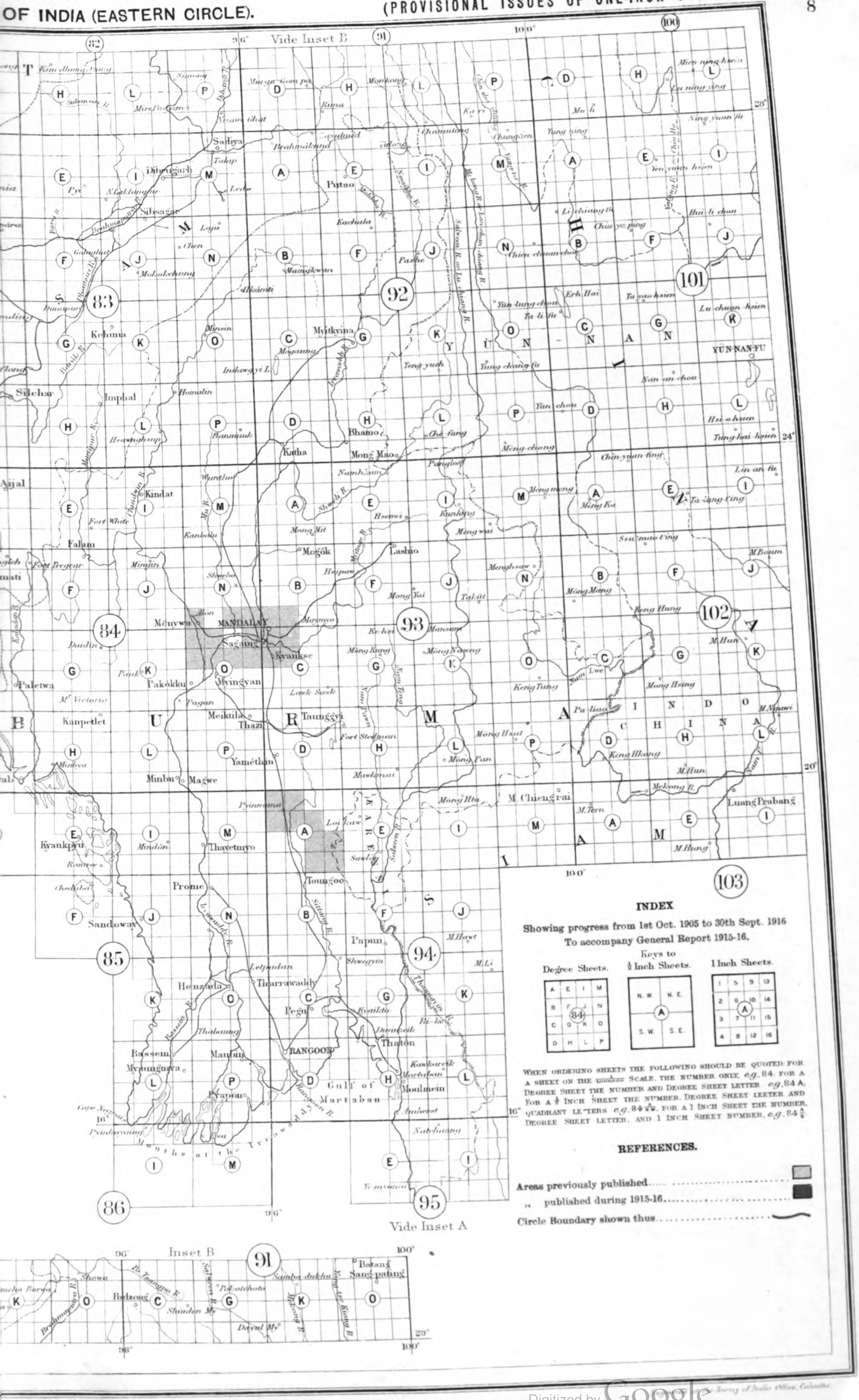
(Eastern Circle).

Digitized by Google



Reg. No. 3437 D., 16.

Digitized by Google

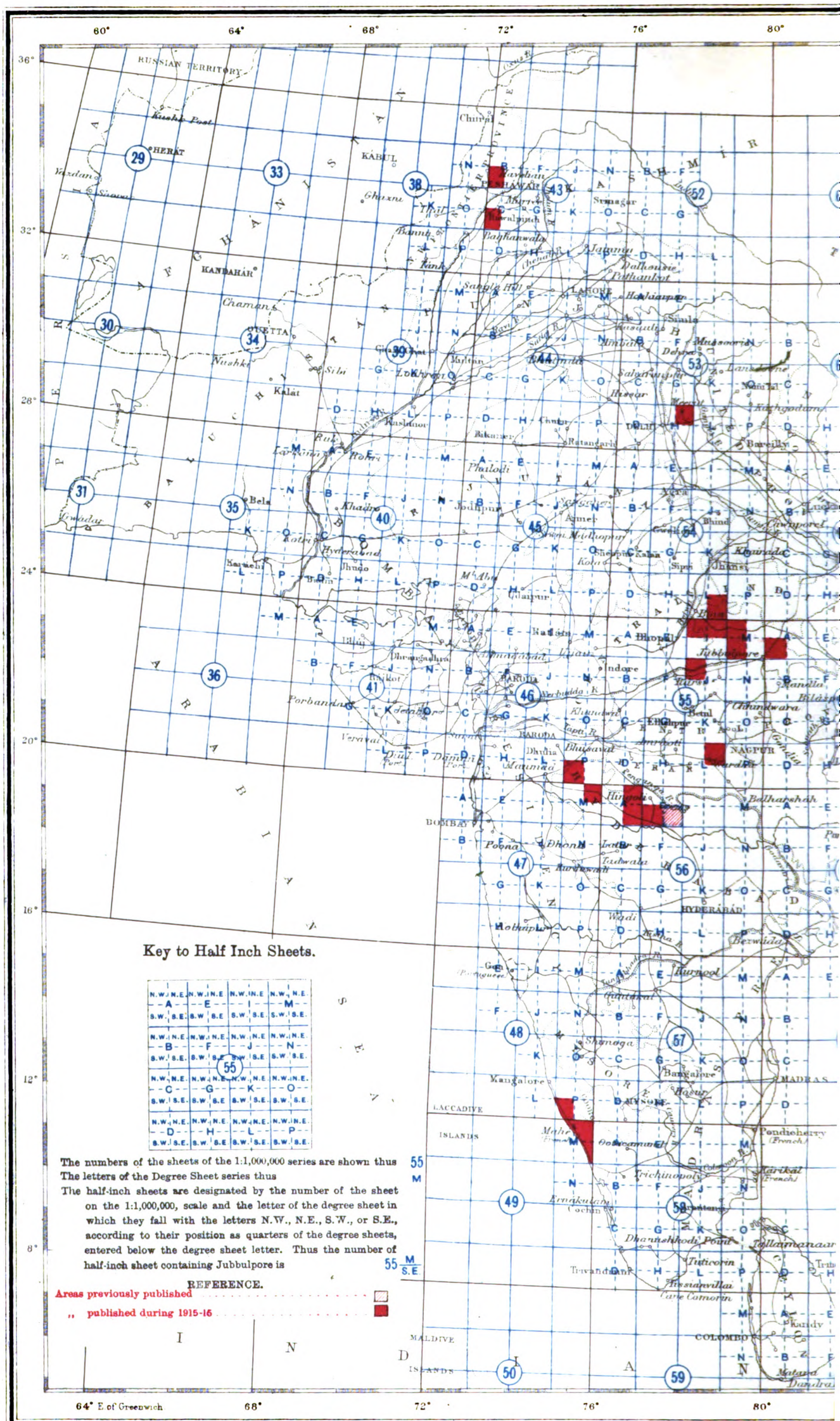


Digitized by Google

Digitized by Google

HALF INCH SERIES.

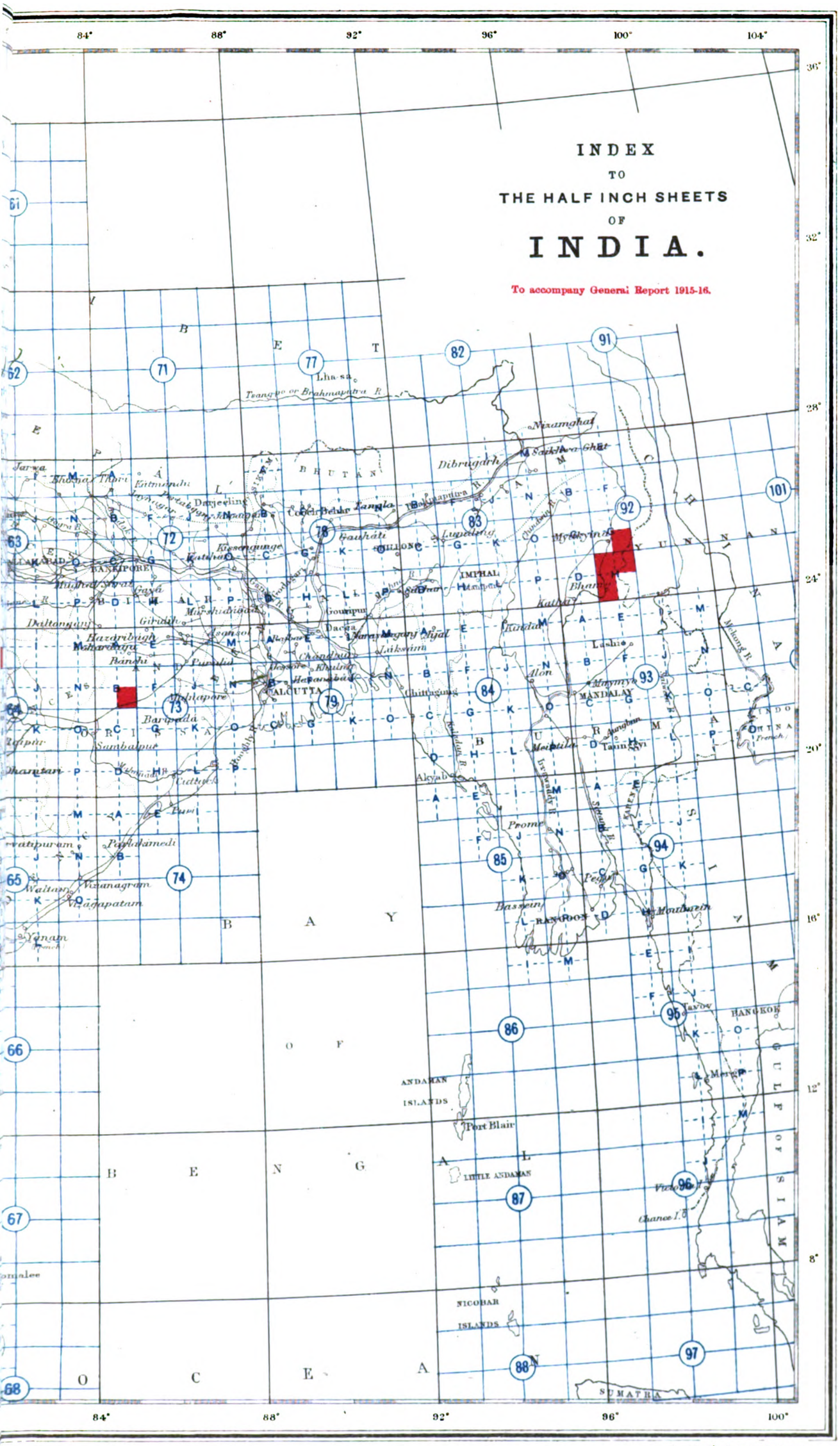
Digitized by Google



Reg. No. 3438 D., 16.

Scale 1 Inch = 1

Digitized by Google



Miles or 1:2,000,000

Litho., S. I. O., Calcutta

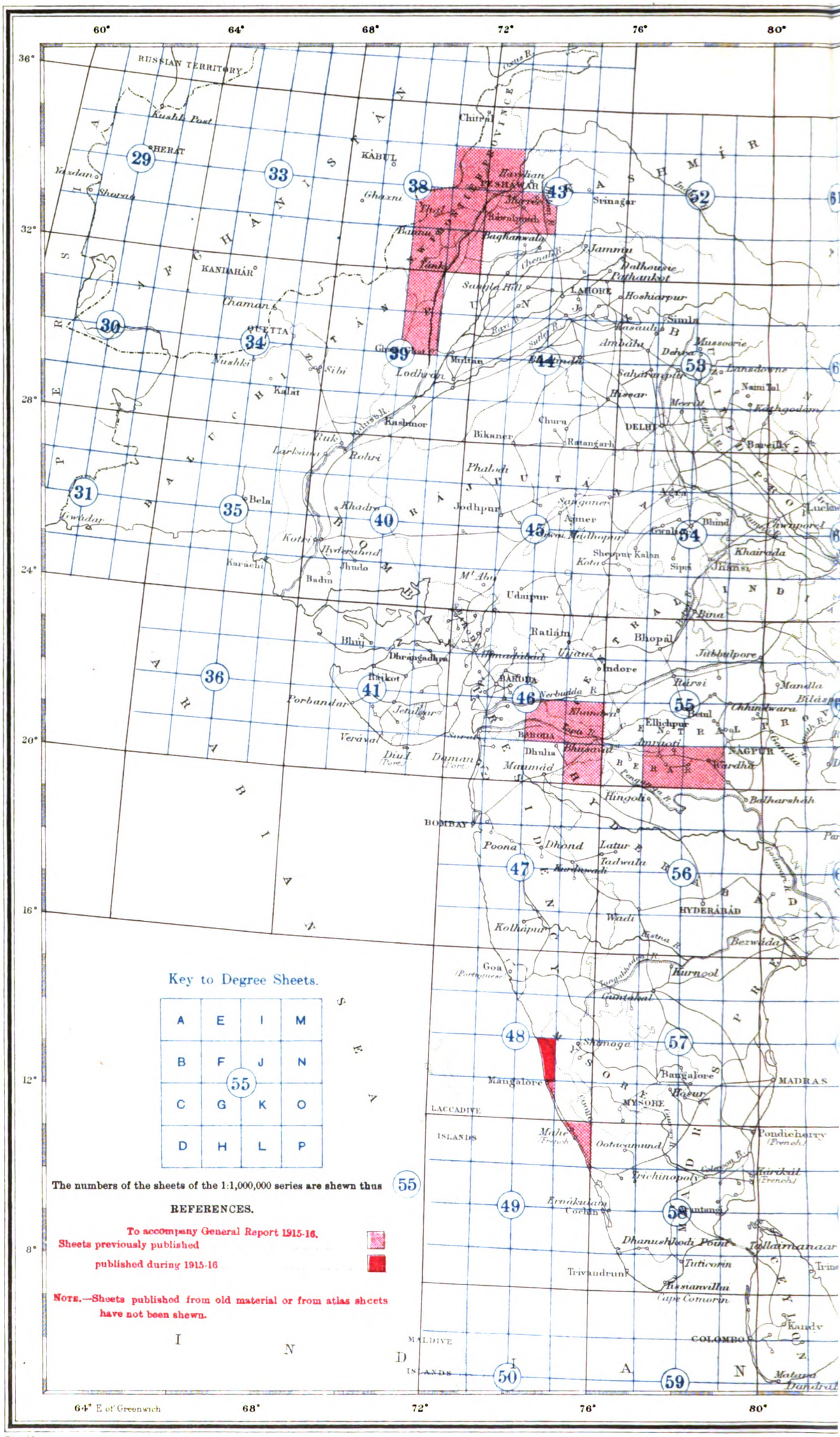
Digitized by Google

Digitized by Google

DEGREE SHEET SERIES

Scale 1 Inch to 4 Miles.

Digitized by Google



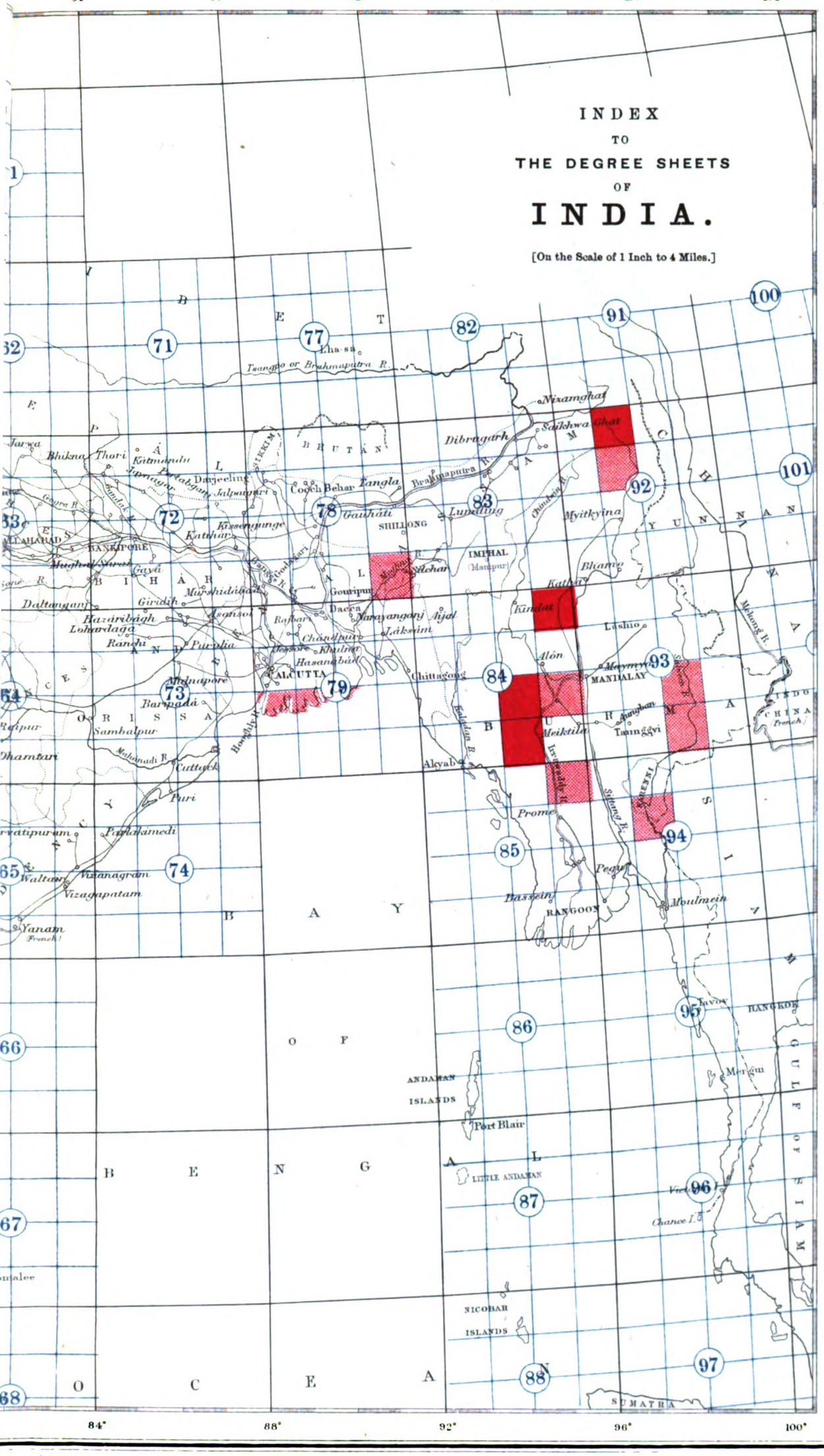
Reg. No. 3439 D., 16.—1400

Scale 1 Inch=1

Digitized by Google

INDEX TO THE DEGREE SHEETS OF INDIA.

[On the Scale of 1 Inch to 4 Miles.]



Miles or 1:1,584,000.

Zinco., S. I. O., Calcutta.

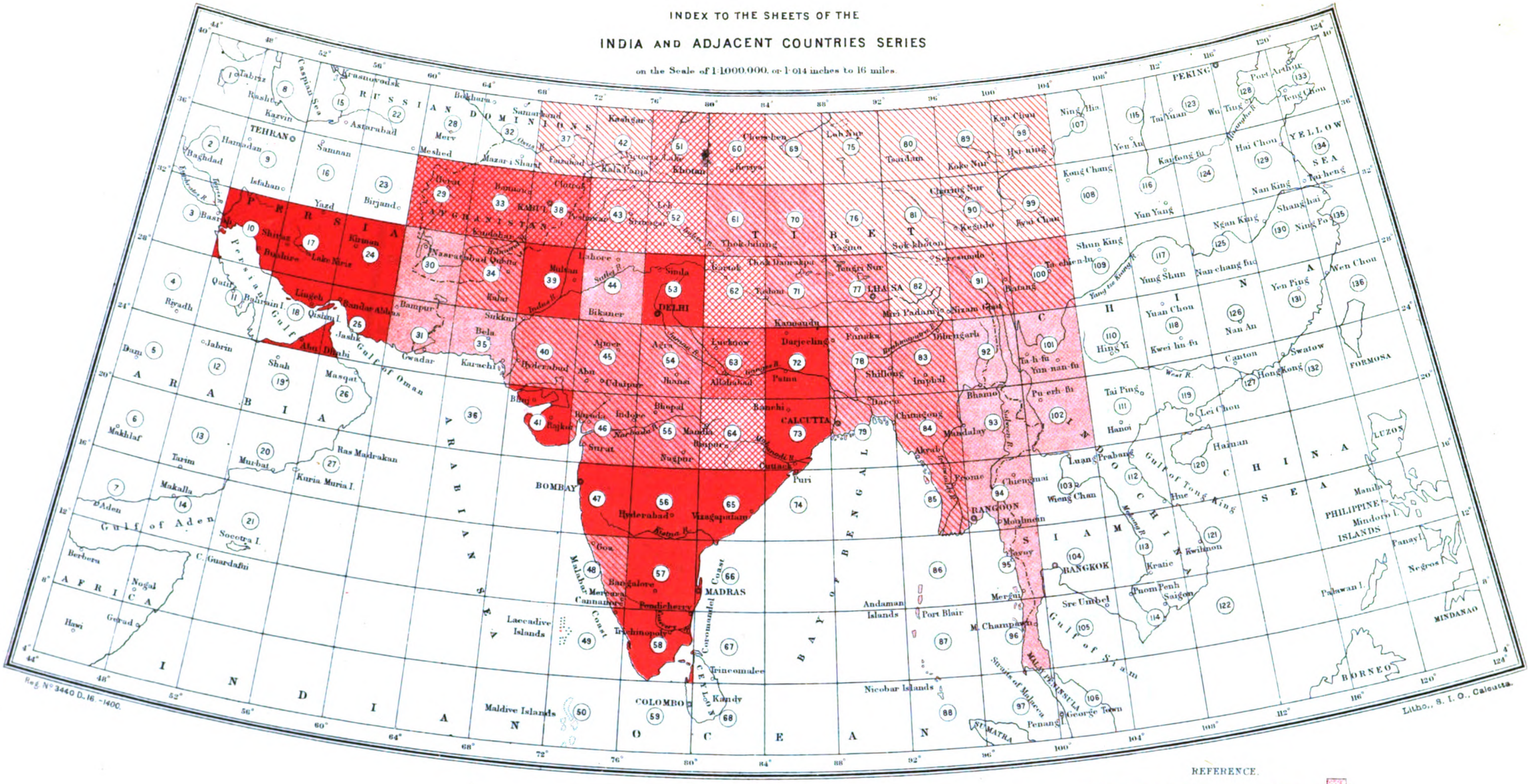
Digitized by Google

Digitized by Google

INDEX TO THE SHEETS OF THE

INDIA AND ADJACENT COUNTRIES SERIES

on the Scale of 1:1,000,000, or 1·014 inches to 16 miles.



Scale 1/10,000,000.

Miles 200 0 200 400 600 800 Miles

REFERENCE.

Sheets published without contours & layers

" " with contours & layers

" under publication

" in hand

To accompany General Report 1915-16.

Digitized by Google

INDIA AND ADJACENT COUNTRIES SE

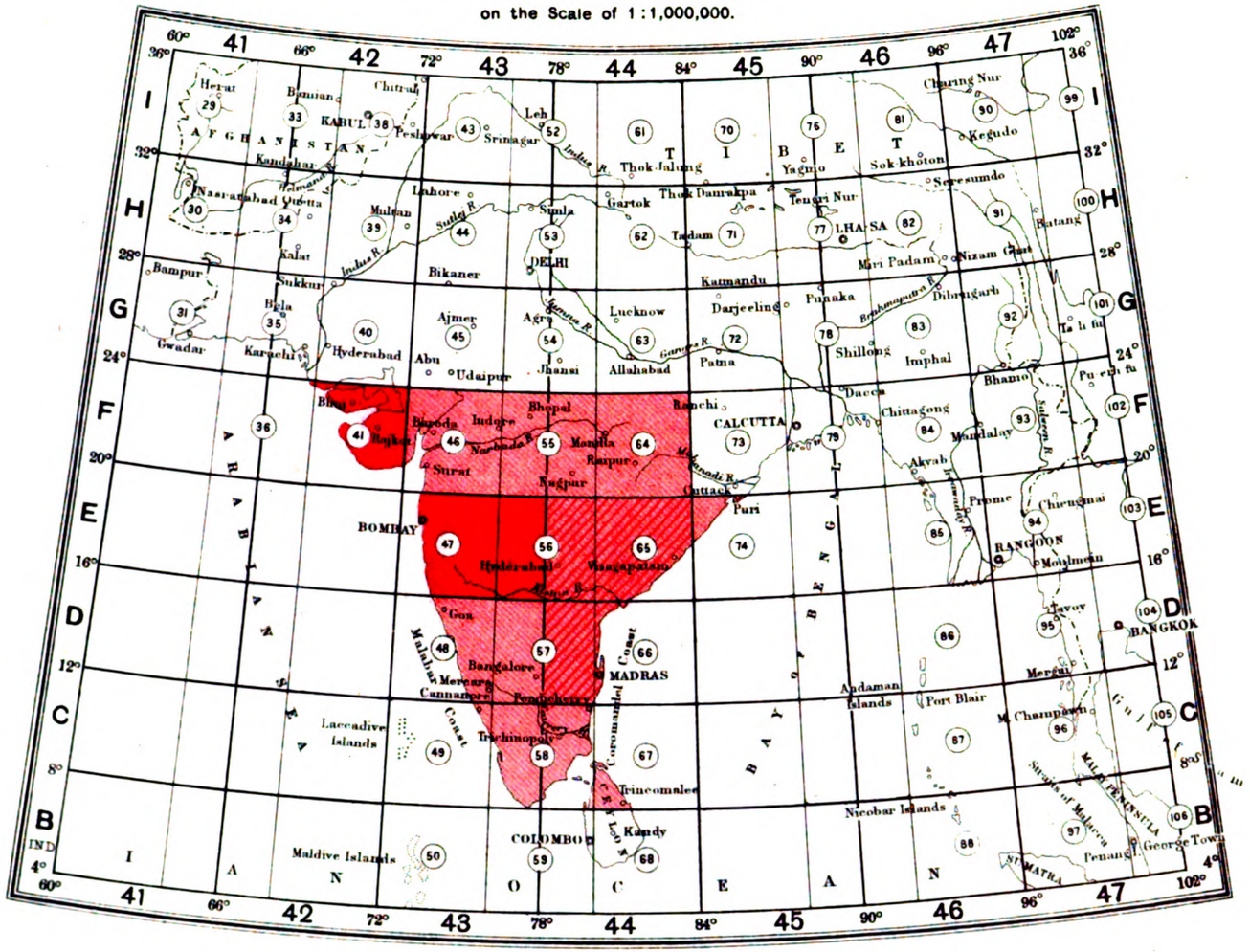
Scale 1:1,000,000.

Digitized by Google

INDEX TO THE SHEETS OF THE

CARTE INTERNATIONALE DU MONDE

on the Scale of 1 : 1,000,000.



The thick lines show the margins of the sheets of the International Map of the World, Scale 1:1,000,000. Each sheet is designated by the letter N (Northern hemisphere), followed by the marginal letter and number corresponding to its position, *e.g.*, the sheet which includes Bombay is N.E-43.

The figures in circles are the numbers of the sheets of the India and Adjacent Countries Series on the Scale of 1:1,000,000.

Scale $\frac{1}{50,000,000}$.

Miles 200 0 200 400 600 800 Miles

REFERENCE

Sheets published

" under publication

" in hand

To accompany General Report 1915-16.

Digitized by Google

INTERNATIONAL SERIES

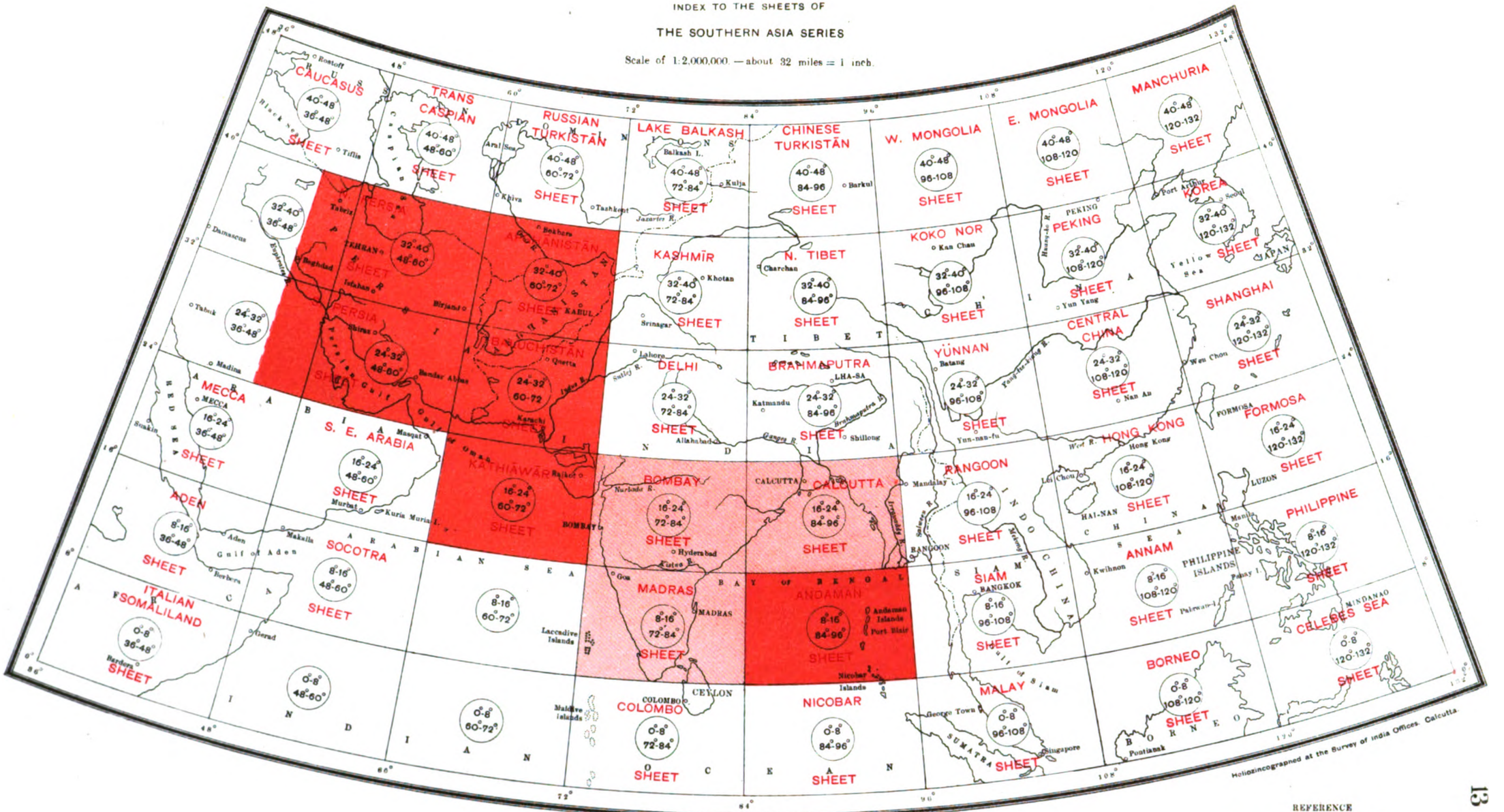
Scale 1:1,000,000.

Digitized by Google

INDEX TO THE SHEETS OF

THE SOUTHERN ASIA SERIES

Scale of 1:2,000,000.—about 32 miles = 1 inch.



REFERENCE

Sheets published.....

" under publication.

" in hand.....

To accompany General Report 1915-16.

Digitized by Google

SOUTHERN ASIA SERIES

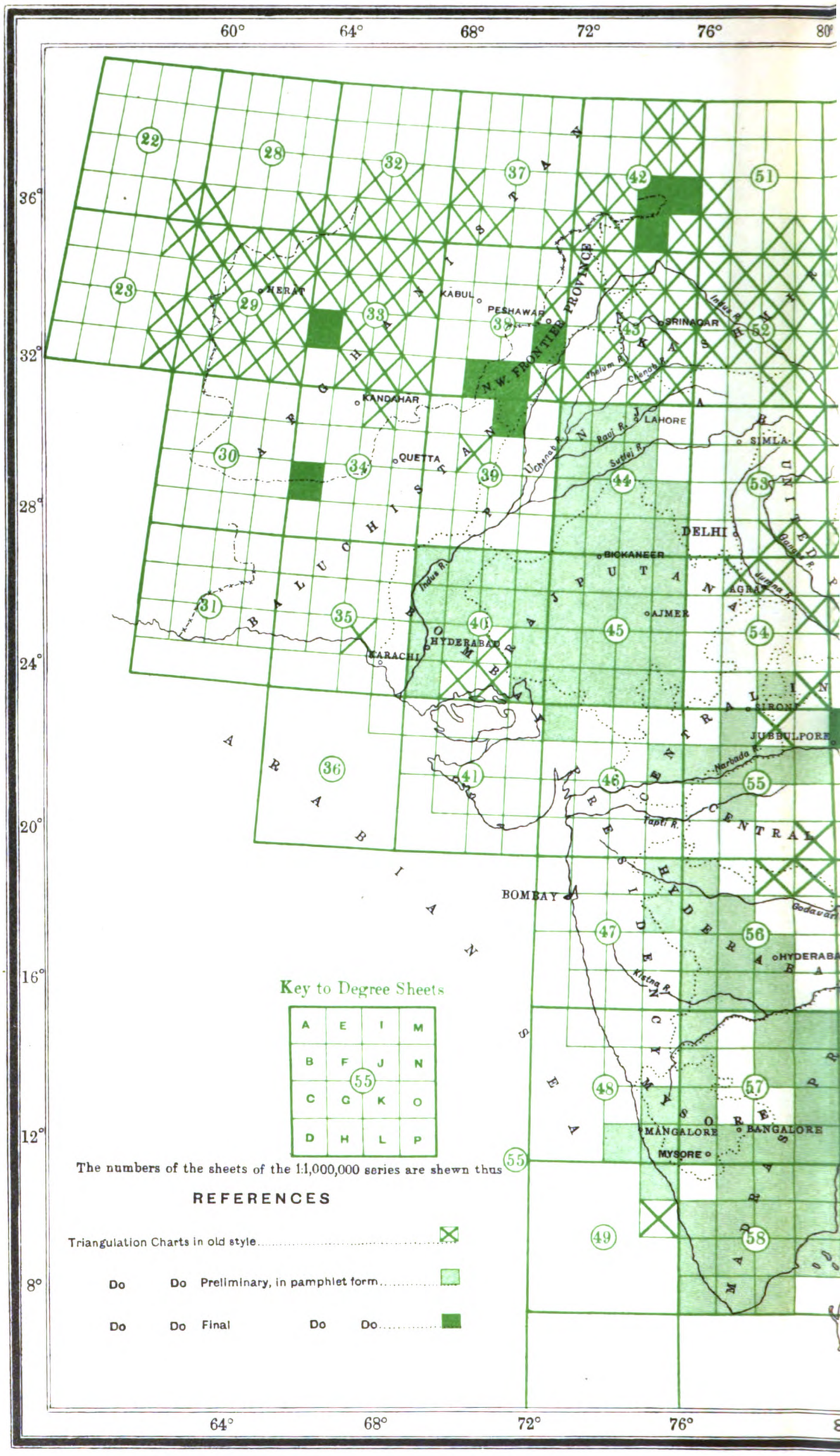
Scale 1:2,000,000.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

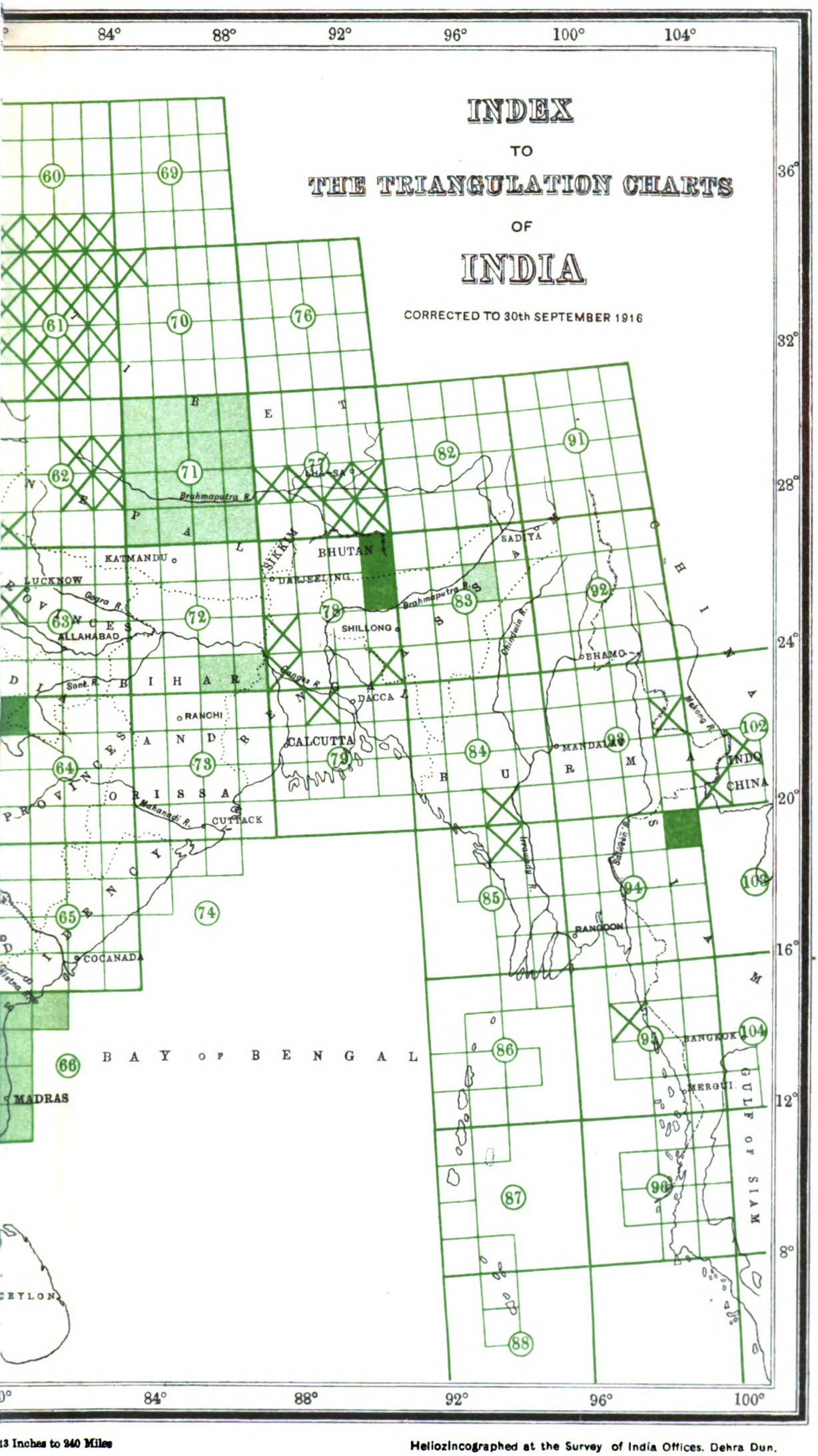


REG. No. 824 D. D. D. 1917 (2D.O.)-S.I.-800

Scale $\frac{1}{15,000,000}$ or 1-

Miles 100 50 0 100

Digitized by Google



13 Inches to 240 Miles

0 300 400 500 Miles

Heliozincographed at the Survey of India Offices. Dehra Dun.

Digitized by Google

Digitized by Google

Digitized by Google

Published under the direction of **Colonel Sir S. G. Burrard, K.C.S.I., R**
1916

Corrected to October 1916.

Digitized by Google

Reg. No. 283 D.D.D.1918-S.I.-420

Digitized by Google

Digitized by Google

Digitized by Google

THE UNIVERSITY LIBRARY
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
SCIENCE LIBRARY

This book is due on the last **DATE** stamped below.
To renew by phone, call **459-2050**.
Books not returned or renewed within 14 days
after due date are subject to billing.

SCI. LIB.

Series 2477

5

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google